Hydro Life Extension Modernization Guides

Volume 1: Overall Process

TR-112350-V1

Final Report, December 1999

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REPORT SUMMARY

This guideline is the first in a series of guidelines for assessing the needs and benefits and evaluating the cost and economic justification of life extension and modernization alternatives at hydroelectric plants and for implementing the selected plan. It also provides a screening procedure and criteria to enable utility personnel to identify which hydroelectric plants are potentially suitable for modernization and which plants promise the most immediate return of the investment.

Background

Hydroelectric power generation is a proven vital source of electricity in the United States and worldwide. Many hydroelectric plants have been reliably generating electricity for more than 50 years. As these facilities continue to age, decisions must be made concerning retirement, continued maintenance and operation, or modernization and redevelopment. As experienced personnel retire and leave utility companies, the need for guidance in making these critical decisions becomes even more important. To address these needs, EPRI has wisely concluded that there is a crucial need for guidance in helping utility managers and owners make critical decisions on the future of their plants. In 1989, EPRI issued 3 volumes of Modernization Guidelines, which have been widely used by the industry. This present series of guidelines will update the 1989 guides and expand them to cover the entire plant.

Objective

To provide an introduction to issues relating to the modernization of hydro plants.

Approach

The project team drew on the results of an extensive literature search and review, as well as solicitation of user needs from EPRI hydro group members, to identify key issues relevant to the modernization of hydro plants and the approaches that utilities and other hydro plant owners are taking today in selection, planning, and decision making.

Results

This guideline analyzes the business considerations that go into modernization planning and implementation including issues of performance, risk, environmental impact, and finance. It provides a screening procedure and criteria to enable utility personnel to identify which hydroelectric plants are potentially suitable for modernization and which plants promise the most immediate return of the investment. The guideline outlines how to devise and implement a modernization plan and illustrates the procedures with a case study. New technologies relevant to hydro plant modernization are discussed in an appendix.

EPRI Perspective
Technical aspects covering Hydromechanical, Electromechanical, Auxiliary Mechanical and Electrical, Civil and other Plant issues, along with Protection, Control and Automation will be contained in the subsequent six volumes to be completed during 2000. The overall aims of the program are:

- To compile information on available and developing technology
- To develop guidelines to assessing needs for life extension and modernization and developing a cost-effective life-cycle plan
- To provide technical data and information required for implementation
- To identify license implications of any upgrades
- To identify improvements that can decrease environmental impacts
- To produce a resource tool for experienced and novice utility engineers

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ABSTRACT

Under contract to the Electric Power Research Institute (EPRI), BC Hydro is developing a 7 Volume set of Guidelines for Life Extension and Modernization of Hydro Plants. These documents, superseding the three volume 1989 Guides published by EPRI, will provide the means to enable utility personnel to identify which hydroelectric plants are potentially suitable for modernization and which plants promise the most immediate return on investment. They will also provide guidance on design and implementation of the selected plan.

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DEFINITIONS

Asset Management - A process using the intellectual capital of the organization and knowledge of the assets to enhance their value.

Asset Register - A system to organize and number assets (or components) in a tiered (or hierarchical) manner, consistent across all plants in a portfolio.

Automation - The provision of equipment and facilities necessary for automatic operation of a generating unit by remote control and protection. Includes stop, start and load change.

Availability - The probability that a piece of equipment or a system will function in a specified manner at any given time.

Availability Factor (AF) - The ratio Available Hours/Period Hours.

Available Hours (AH) - The total number of hours that a unit is available. Available Hours are the sum of Service Hours and Reserve Shutdown Hours.

Cash Flow - Net income adjusted for non-cash items and capital investments. Most common non-cash items are amortization and depreciation.

Contingency Allowance - Funds provided in a project estimate to allow for potential costs which cannot be specifically identified at the time of the estimate preparation but which can be anticipated to occur with varying degrees of probability during implementation of the project.

Cost of Service - The cost performance requirements for each plant defined by the customers, stakeholders and owners.

Dependability - The collective term used to describe the performance of a system with regards to each of the following factors: reliability, maintainability, availability and safety.

Depreciation - Allocating the capital cost of plant, property and equipment to the period in which their benefits are derived, usually over the useful life of the asset.

Economic Evaluation - Represents the analysis of cash flow data to support the decision-making function. In this document, economic evaluations consider all relevant period cash flow items prior to income tax effects.

Engineer's Estimate - Detailed cost estimate prepared by the Owner's Engineer or representative on the basis of contract specifications during the tender period to assist in the evaluation and comparison of tenders.

Escalation - The provision in actual or estimated costs for an increase in the cost of equipment, material, labour, etc., over those specified in the contract, due to continuing price level changes over time.

Financial Evaluation - Represents the analysis of financial and accounting data to support the decision-making function. In this document, financial evaluations consider all relevant period income items prior to income tax effects.

Forced Outage (FO) - The automatic removal from service of a unit, due to a component failure or other condition jeopardizing the integrity of the unit.

Forced Outage Factor (FOF) - The ratio Forced Outage Hours/Period Hours.

Forced Outage Hours (FOH) - The total number of hours that a unit is unavailable due to Forced Outages.

Forced Outage Rate (FOR) - The ratio Forced Outage Hours/Forced Outage Hours plus Service Hours.

Inflation - Loss of purchasing power of currency over a period of time, made up by increasing base constant dollar values by assumed or index values.

Instantaneous Availability - The probability that an item is in a state to perform a required function under given conditions at a given instant of time, assuming that the required external resources are provided.

Level of Service - The plant performance requirements defined by the customers (market) stakeholders and owners.

Life Cycle Management - A holistic and iterative approach to management of a powerplant which considers all aspects prior to making decisions on life extension and modernization. In general the process includes: setting goals, inventory analysis, assessment of options and selection and implementation.

Life Extension - The restoration of plant dependability and sustainability.

Maintainability - The probability that a piece of equipment or a system can be repaired in a specified period of time.

Maintenance Outage (MO) - The removal from service of a unit before the next *Planned Outage*, for a specific maintenance activity. This is normally due to a condition jeopardizing the integrity of the unit.

Maintenance Outage Hours (MOH) - The total number of hours that a unit is unavailable due to Maintenance Outages.

Mean Planned Outage Duration (MPOD) - The ratio Planned Outage Hours/number of planned outages.

Mean Time between Failures (MTBF) - The mean operating time between two consecutive failures of a piece of equipment or a system. For repairable equipment it is the sum of MTTF and MTTR. MTBF is the ratio of (total operating time + total repair time)/(number of failures).

Mean Time to Failure (MTTF) - The mean operating time between the initial start or start after a repair and the failure of a piece of equipment or a system. MTTF is the ratio of (total operating time)/(number of failures).

Mean Time to Planned Outage (MTTPO) - The ratio Service Hours/number of Planned Outages.

Mean Time to Repair (MTTR) - The mean time that a repairable piece of equipment or a repairable system is in a failed state, excluding any time disassociated with the corrective action.

Mean Time to Unplanned Outage (MTTUO) - The ratio Service Hours/number of Forced and Maintenance Outages.

Mean Unplanned Outage Duration (MUOD) - The ratio Maintenance Outage Hours plus Forced Outage Hours/number of Forced and Maintenance Outages.

Modernization - The improvement of level of service, and cost of service, measured by plant output and/or flexibility.

Outage - The removal from service of a unit.

Partial Automation - Remote or preprogrammed control over the watt and var output of the plant. Start-up and shutdown normally requires on site operator intervention.

Period Hours (PH) - The number of calendar hours in the period under consideration (usually 1 year).

Planned Outage (PO) - The removal from service of a unit for inspections, tests, and repairs, in accordance with a plan developed well in advance of the Outage.

Planned Outage Factor (POF) - The ratio Planned Outage Hours/Period Hours.

Planned Outage Hours (POH) - The total number of hours that a unit is unavailable due to Planned Outages.

Internal Rate of Return (IRR) - The interest rate that makes the present worth of the project's cash flow equal to the present worth of the project's investment cost.

Redevelopment - Replacement of an existing plant with a new structure, unit(s) and infrastructure, while maintaining the water retaining facilities.

Rehabilitation - The replacement or improvement of components which have been the cause of high maintenance and repair, or for which failure, due to age, is expected in the foreseeable future.

Reliability - The probability that a piece of equipment or a system will function in a specified manner for a given period of time or number of cycles.

Reserve Shutdown Hours (RSH) - The total number of hours that a unit is available but not synchronized to the system.

Retirement - The planned decommissioning of a plant.

Risk - The likelihood of a future hazardous event that causes unacceptable consequences. It is measured as:

the probability of injury (including death) to people and the life safety consequences.

the probability of property, environmental or social damage and the consequences, usually in monetary terms.

Safety - A type of protection in which additional measures are applied so as to give increased security against the possibility of harm to the operator, equipment, system performance, etc.

Salvage Value - The estimated amount that will be received at the time the asset is disposed of, less the costs of removal, disposal, remediation and restoration.

Service Factor (SF) - The ratio Service Hours/Period Hours.

Service Hours (SH) - The total number of hours that a unit is synchronized to the system.

Sustainability - The ability of the hydroplant to continue in operation with regard to licencing, regulatory compliance, environmental issues and catastrophic risk.

Unavailability Factor (UF) - The ratio Planned Outage Hours plus Maintenance Outage Hours plus Forced Outage Hours/Period Hours.

Unplanned Outage Factor (UOF) - The ratio Forced Outage Hours plus Maintenance Outage Hours/Period Hours.

Upgrading - The modernization of existing equipment to increase efficiency, increase life expectancy, improve availability and/or reduce labour intensive maintenance.

Uprating - The replacement or improvement of components to increase the unit output.

CONTENTS

1 INTRODUCTION 1-1
1.1 Need For Guidelines 1-1
1.2 Objectives and Scope of The Guidelines 1-3
1.3 Concepts 1-4
Life Cycle Management 1-4
Life Extension 1-5
Modernization 1-6
Need and Timing of Plant Investments 1-7
1.4 How to Use the Guidelines 1-8

2 BACKGROUND 2-1
2.1 Utility Approach to Life Extension and Modernization 2-1
2.1.1 Organizations and Change 2-1
2.1.2 Policies and Principles 2-3
2.1.3 Process Issues 2-4
Assumptions 2-4
Approvals 2-4
User Requirements 2-5
2.1.4 New Approaches 2-6
2.1.5 Resourcing and the Use of Consultants 2-6
2.2 Industry-Owned or Non-Utility Plants 2-8
Industry-Owned Hydro Plants 2-8
Non-Utility Hydro Plants 2-9
2.3 Business Considerations 2-10
2.3.1 Performance Indicators 2-10
Dependability 2-11
Reliability 2-12
Maintainability 2-12

Availability 2-13
Sustainability 2-13
Output 2-13
Flexibility 2-14
Profitability/Importance 2-14
2.3.2 Risk Issues 2-14
Risk Consideration 2-14
Business Critical Risks 2-15
Life Safety Risks 2-15
Financial Risks 2-16
Risk Management 2-16
2.3.3 Environmental Considerations 2-17
Existing Environmental Issues 2-18
Technology Improvements 2-20
Water Quality 2-21
Fish Passage 2-22
Research and Development Activities 2-24
2.3.4 Commercial Considerations 2-26
Parts of a Typical Contract 2-26
Types of Contracts 2-27
Types of Technical Specifications 2-27
Arranging Contracts to Limit Risk or Price 2-28
2.3.5 Estimating Considerations 2-28
Types of Estimates 2-29
Overview Estimates 2-29
Feasibility Estimates 2-29
Design Estimates 2-29
Engineer's Estimates 2-29
Estimating Techniques 2-30
Estimating Contingencies 2-31
Estimating Procedures 2-31

***3* SCREENING AND PRIORITIZATION 3-1**
Screening for Life Extension 3-1
Screening for Modernization 3-2

3.1 Identify Obvious Non-Candidates for Screening 3-3
3.2 Rate Importance of Plant 3-4
3.3 Rate Dependability as Indicator of Life Extension Requirements 3-5
3.4 Rate Sustainability as Indicator of Life Extension Requirements 3-9
3.5 Calculate Overall Rating for Life Extension 3-11
3.6 Rate Output as Indicator of Modernization Opportunities 3-11
3.7 Rate Flexibility as Indicator of Modernization Opportunities 3-16
3.8 Calculate Overall Rating for Modernization 3-18
3.9 Prioritize Work for Life Extension or Modernization 3-24

4 LIFE EXTENSION AND MODERNIZATION PLAN 4-1
4.1 Plan Plant Survey 4-3
Organization of the Work 4-3
4.2 Collect and Analyze Data 4-4
Asset Register 4-5
Operational and Cost Data 4-5
Condition Assessment 4-8
Documentation 4-8
4.3 Inspect Equipment and Structures 4-13
4.4 Identify Risks 4-14
4.5 Identify Needs and Opportunities 4-19
4.6 Develop Plant Strategies 4-23
Operations Strategies 4-23
Workforce and Maintenance Planning Strategies 4-24
Risk Strategies 4-25
Product Portfolio Improvements 4-25
4.7 Align Needs and Opportunities with Plant Strategies 4-26
Life Extension (Needs) Projects 4-27
Modernization (Opportunity) Projects 4-29
Justification and Alignment with Strategies 4-29
Licensing and Environmental Consideration 4-31
Revision to Needs and Opportunities Table 4-31
4.8 Assign Costs, Benefits, and Timing to Selected Needs and Opportunities 4-35
Costs 4-35
Benefits 4-35

Timing 4-36
4.9 Complete the Economic/Financial Evaluation 4-36
Purpose of the Evaluation 4-36
Model Design 4-37
Model Limitations 4-37
Forecasting the Economic/Financial Value of Plant Life Extension 4-38
Collecting Input Assumptions 4-38
Populating the Model 4-39
Reviewing the Results 4-41
Forecasting the Economic/Financial Value of Plant Modernization 4-41
Generating Modernization Options 4-41
4.10 Document Life Extension and Modernization Plan 4-42
4.11 Review Life Extension and Modernization Plan 4-43
Measuring Results 4-43
Performance 4-43
Monitoring Requirements 4-43
Updates of Strategies and Plans 4-44

***5* APPROACH FOR MULTI-PLANT PORTFOLIO 5-1**
5.1 Purpose 5-2
5.2 Process 5-3
Select Investment Alternatives 5-3
Criteria 5-4
Tools 5-4
5.3 Implementing and Managing Investment Activities 5-4

***6* INSTITUTIONAL AND REGULATORY ISSUES 6-1**
6.1 Introduction 6-1
Purpose and Scope of Section 6-1
Why Institutional and Regulatory Issues are Important? 6-1
How to use this Section 6-2
6.2 FERC Hydropower Licensing Program 6-3
Who is FERC? 6-3
Brief History of FERC 6-3
FERC's Role in Hydropower Regulation 6-5

Licensing Program 6-5
Original Licences 6-5
New Licences (Re-Licences) 6-6
Exemptions 6-7
Dam Safety 6-8
FERC Licensing Processes 6-9
Traditional Process 6-9
Preparation of Application 6-9
Processing 6-10
Licence Issuance 6-10
Alternative Processes 6-11
Alternative APEA Process 6-11
Third Party Contracting EIS 6-13
Other Hybrid Processes 6-14
Amendment Process 6-14
Introduction 6-14
When is an Amendment Needed? 6-15
Types of Amendment 6-15
Amendment Applications 6-16
6.3 Other Permits, Licences and Agreements 6-17
Clean Water Act 6-17
Wetlands Permits 6-17
Special Use Permits 6-17
State and Local Permits 6-17
Agreements 6-18
6.4 Typical Licensing Issues 6-18
“Best Adapted” Comprehensive Development 6-18
Resource Utilization 6-19
Balancing of Power and Non-power Values 6-19
Cumulative Impacts 6-19
Streamflow Impacts 6-20
Water Quality 6-20
Fishery Impacts 6-21
Wildlife 6-21

Threatened and Endangered Species (TES) 6-21
Geology and Soils 6-22
Recreation Impacts 6-22
Historical and Cultural Resources 6-22
Construction Impacts 6-22
Access 6-23
Reopeners 6-23
6.5 Screening and Ranking Candidates 6-24
Purpose of this Section 6-24
Screening Process 6-24
Ranking Potential Candidates 6-25
6.6 Developing a Licensing Plan 6-25
Introduction 6-25
Goals 6-26
Participants 6-26
Issues 6-27
Constraints 6-27
Fatal 6-27
Negotiable 6-28
Risks 6-28
Opportunities 6-28
Determine your Licensing Category 6-28
No FERC Jurisdiction? 6-29
Licence 6-29
No Action 6-30
Capacity-related Amendment 6-30
Non-capacity-related Amendment 6-30
Re-licence 6-31
Exemption 6-31
No Action 6-31
Amendment 6-32
Reclassification 6-32
Consider Licensing Options 6-32
Licence Amendment 6-32

New Licence 6-33
Licence Exemption 6-33
Traditional or Alternative Process 6-34
Decision-making 6-34
Action Plan 6-34
6.7 Glossary of Licensing Terms 6-35

***7* FEASIBILITY 7-1**
7.1 Plan Feasibility Process 7-4
7.2 Additional Testing 7-5
7.3 Improved Assessment of Condition 7-7
7.4 Use Analytical Methods 7-8
Power Studies 7-8
Turbine Modelling by Numerical Methods 7-8
Buildability 7-9
Value Engineering 7-9
7.5 Evaluate Issues 7-10
Environmental and Social Impacts 7-10
Regulatory and Licensing Requirements 7-11
Risk and Insurance 7-12
7.6 Evaluate Options 7-14
Cost Estimates of Each Option 7-15
Benefits of Each Option 7-16
7.7 Optimize Options 7-16
7.8 Develop Approach to Modernization 7-17
Description of Modernization Project 7-18
Project Costs, Benefits and Schedule 7-18
Financing, Risk and Insurance Plan 7-19
Implementation Plan 7-19
7.9 Document Results 7-19

***8* PROJECT DEFINITION AND IMPLEMENTATION 8-1**
8.1 Confirm Project Requirements and Project Plan 8-4
8.2 Obtain Regulatory/Licensing Approvals 8-6
8.3 Obtain Financing (Internal or External) 8-7

8.4 Conduct Engineering Studies and Detail Design 8-7
Additional Tests and Studies 8-7
Detail Design of Infrastructure 8-8
Standard Designs 8-8
8.5 Procure Improvements 8-9
Procurement Options 8-9
Technical Specifications 8-9
Risk Sharing - Bonuses, Penalties, Liquidated Damages 8-9
Invitation to Tender 8-10
Evaluation and Award of Contract 8-11
8.6 Construct/Install Improvements 8-12
Off-Site Manufacture and Quality Control 8-13
Transportation to Site 8-13
Installation and Construction 8-13
Construction Management 8-14
Contract Management 8-14
Testing and Commissioning 8-15
Training 8-16
8.7 Document Process 8-16

A APPENDIX A: NEW TECHNOLOGIES A-1
A.1 Introduction A-1
A.2 Hydromechanical Plant A-2
A.2.1 Turbine Runners A-2
Design A-2
Materials A-4
Manufacture A-5
Repair Techniques A-5
Testing A-6
A.2.2 Governor A-6
A.2.3 Wicket Gates and Stay Vanes A-7
A.2.4 Draft Tubes A-8
A.2.5 Self Lubricated Bushings A-8
A.2.6 Turbine Bearings A-9
Water Lubricated A-9

PTFE Bearings A-9
A.2.7 Condition Monitoring A-9
A.3 Electromechanical A-10
A.3.1 Generator A-10
Design A-11
Materials A-11
Operation A-12
Innovative Construction Methods During Modernization A-12
A.3.2 Excitation and Voltage Regulation A-12
A.3.3 Synchronizer A-13
A.3.4 Condition Monitoring A-14
A.4 Auxiliary Mechanical A-15
A.4.1 Air Compressors A-15
A.4.2 Cranes A-15
A.4.3 Emergency Generator A-15
A.4.4 Fire Protection A-16
A.4.5 Heating, Ventilation and Air Conditioning (HVAC) A-16
A.4.6 Environment A-17
Temperature A-17
Dissolved Oxygen A-17
Contaminants A-18
A.5 Auxiliary Electrical A-18
A.5.1 Generator Transformer A-18
A.5.2 Station Service and Auxiliary Transformers A-18
A.5.3 AC Systems A-18
A.5.4 DC Systems A-19
A.6 Site and Civil Works A-19
A.6.1 Dams A-19
Dam Safety A-20
Dam Repair Techniques A-20
Alkali-Aggregate Reaction (AAR) A-20
Dam Leakage A-21
Risk Assessment A-21
A.6.2 Structural Soil and Drainage Systems A-21

A.6.3 Penstocks and Trashracks A-22
Penstocks A-22
Trashracks A-22
A.6.4 Buildings and Structures A-22
A.6.5 Environment A-23
Fish Protection Systems A-23
Water Quality Enhancement Systems A-23
A.7 Protection and Controls A-23

***B* APPENDIX B: BACKGROUND TO MODERNIZATION OPPORTUNITIES B-1**
B.1 Introduction B-1
B.2 Energy B-2
B.3 Portfolio Services B-3
B.4 Ancillary Transmission Services B-5
B.5 Flexible Operation B-6
B.6 Automation B-7
B.7 Other Services B-8

***C* APPENDIX C: CASE HISTORY C-1**
C.1 Synopsis C-1
C.2 Background C-1
C.3 Screening and Prioritization C-2
C.3.1 Life Extension Rating C-2
Importance C-3
Dependability C-3
Sustainability C-4
Calculate Overall Rating for Life Extension C-4
C.3.2 Modernization Rating C-5
Output C-5
Flexibility C-6
Calculate Overall Rating for Modernization C-7
Prioritize Work for Life Extension or Modernization C-7
C.4 Life Extension and Modernization C-7
C.4.1 Plant Survey C-7
C.4.2 Plant Strategies C-8

Operations....C-8
Workforce and Maintenance Planning....C-8
Risk....C-9
Product Portfolio Improvements....C-9
C.4.3 Selected Needs and Opportunities....C-9
C.4.4 Financial Evaluation....C-9
C.4.5 Life Extension and Modernization Plan....C-11
C.5 Feasibility....C-11
C.5.1 Options for Feasibility....C-11
C.5.2 Assessment, Tests and Analysis....C-11
Evaluate Issues....C-12
C.5.3 Evaluation of Options....C-12
C.5.4 Optimization of Options....C-13
C.5.5 Selection of Feasible Project....C-13
C.6 Project Definition and Implementation....C-14
C.6.1 Project Plan....C-14
C.6.2 Licensing and Financing....C-14
Licensing....C-14
Financing....C-15
C.6.3 Project Approval....C-15
C.6.4 Engineering....C-15
C.6.5 Procurement....C-15
C.6.6 Construction....C-16
C.6.7 Documentation....C-16

_D_ APPENDIX D: ANNOTATED BIBLIOGRAPHY OF LITERATURE RELATED TO VOLUME 1....D-1

LIST OF FIGURES

Figure 1-1 Options for the Future of Aging Powerplants 1-2
Figure 1-2 Overall Life Extension and Modernization Process (Vol. 1) 1-10
Figure 1-3 Overall Life Extension and Modernization Process (Volumes 2 to 7) 1-10
Figure 2-1 Project Cost Estimates and Schedules (Standard Procedure) 2-32
Figure 3-1 Screening and Prioritization Process 3-3
Figure 3-2 Step 3-3: Ratings for Operating and Maintenance Costs 3-8
Figure 4-1 Life Extension and Modernization Plan 4-2
Figure 4-2 Step 4-7: Development of Modernization Plans 4-28
Figure 4-3 Process and Data Flow of the Electronic Evaluation Template 4-38
Figure 5-1 Selecting and Prioritizing Life Extension and Modernization Activities 5-2
Figure 8-1 Implementation 8-1
Figure 7-1 Feasibility 7-2
Figure 7-2 Process and Data Flow of the Electronic Evaluation Template 7-17
Figure C-1 Life Extension Plan Model Results C-97
Figure C-2 Modernization Plan 5% Efficiency Increase Results C-98
Figure C-3 Feasibility - 5% Efficiency Increase Results C-99

LIST OF TABLES

Table 1-1 Table of Contents for Volume 1 and Volumes 2 to 7 1-11
Table 2-1 Major Environmental Issues Relating to Hydropower Operation (from M. Warton et al) 2-19
Table 2-2 Aspects of Hydro Plant Operation with Potential for Environmental Impacts 2-20
Table 2-3 Hydropower R&D Projects (from P.A. Brookshier et al) 2-25
Table 2-4 Hydro Modernization Projects - Construction Costs Estimates - Guidelines for Contingencies 2-31
Table 3-1 Step 3-2: Importance Indicators 3-5
Table 3-2 Step 3-2: Importance Ratings 3-5
Table 3-3 Step 3.3: Dependability Indicators 3-6
Table 3-4 Step 3-3: Dependability Ratings 3-7
Table 3-5 Step 3-4: Sustainability Indicators 3-9
Table 3-6 Step 3-4: Sustainability Ratings 3-10
Table 3-7 Step 3-6: Output Indicators 3-12
Table 3-8 Step 3-6: Output Ratings 3-13
Table 3-9 Step 3-6: Modernization Options for Output 3-14
Table 3-10 Step 3-6: Life Of Hydropower Plant Systems 3-15
Table 3-11 Step 3-7: Flexibility Indicators 3-16
Table 3-12 Step 3-7: Flexibility Ratings 3-17
Table 3-13 Step 3-2 Worksheet: Plant Importance 3-18
Table 3-14 Step 3-3 Worksheet: Dependability 3-19
Table 3-15 Step 3-4 Worksheet: Sustainability 3-20
Table 3-16 Step 3-5 Worksheet: Overall Ratings for Life Extension (For Each Plant) 3-21
Table 3-17 Step 3-6 Worksheet: Output 3-22
Table 3-18 Step 3-7 Worksheet: Flexibility 3-23
Table 3-19 Step 3-8 Worksheet: Overall Ratings for Modernization (For Each Plant) 3-24
Table 4-1 Plant Survey Methodology for Assessing Needs and Opportunities 4-3
Table 4-2 Asset Register 4-9
Table 4-3 Step 4-2: Data Analysis Table for Hydro Plant 4-10
Table 4-4 Step 4-2: Sample Only – Data Analysis and Inspection Results Table for Equipment and Structures 4-12
Table 4-5 Step 4-4: Risk Identification 4-17

Table 4-6 Step 4-5: Needs and Opportunities 4-21
Table 4-7 Step 4-7: Strategies/Opportunities Link Sheet 4-30
Table 4-8 Step 4-7: Needs and Opportunities (Revised To Align With Plant Strategies) 4-33
Table 4-9 Step 4-9: Populating the Model 4-40
Table 5-1 Examples of Criteria for Ranking Life Extension and Modernization Activities 5-5
Table 6-1 Comparison of Traditional and APEA Licensing Processes 6-12
Table 7-1 Sequence of Feasibility, Project Definition and Implementation Activities 7-3
Table 7-2 Examples of Additional Tests 7-6
Table 8-1 Implementation 8-2
Table 8-2 Sample Statement of Objectives 8-5
Table B-1 Opportunities to Increase Energy Output from Hydro Plants B-2
Table B-2 Product Portfolio Improvements B-3
Table B-3 Opportunities to Increase Ancillary Transmission Services from Hydro Plant B-5
Table B-4 Opportunities to Increase Flexible Operation from Plants B-6
Table B-5 Opportunities to Increase Automation from Hydro Plants B-7
Table B-6 Opportunities to Increase Other Services from Hydro Plants B-8
Table C-1 Step 3-2 Worksheet: Plant Importance C-17
Table C-2 Step 3-3 Worksheet: Dependability C-18
Table C-3 Step 3-4 Worksheet: Sustainability C-19
Table C-4 Step 3-5 Worksheet: Overall Ratings for Life Extension (For Each Plant) C-20
Table C-5 Step 3-6 Worksheet: Output C-21
Table C-6 Step 3-7 Worksheet: Flexibility C-22
Table C-7 Step 3-8 Worksheet: Overall Ratings for Modernization (For Each Plant) C-23
Table C-8 Table 4-3 – Step 4-2: Data Analysis Table for Francis Hydro Plant C-24
Table C-9 Table 4-4 – Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures C-28
Table C-10 Table 4-5 – Step 4-4: Risk Identification C-61
Table C-11 Table 4-6 – Step 4-5: Needs C-71
Table C-12 Table 4-6 – Step 4-5: Opportunities C-87
Table C-13 Table 4-7 – Step 4-6: Strategies/Opportunities Link Sheet C-93
Table C-14 Table 4-8 – Step 4-7: Opportunities C-95

1
INTRODUCTION

1.1 Need For Guidelines

Many hydroelectric projects in North America have been reliably generating electricity for over 80 years. As these facilities age, decisions have to be made on their futures, which can include retirement, life extension, modernization or redevelopment.

Plant life extension and modernization are increasingly important considerations among owners and managers of older hydro plants. Excellent, financially rewarding opportunities can be achieved by taking advantage of state-of-the-art improvements in equipment, technology, operation, maintenance and management. However, in an increasingly complex business environment and a rapidly escalating time of change, decisions are not straightforward. Appropriate levels of knowledge and the organizational capability to take advance of them, are essential ingredients.

Life cycle management, as applied to the hydroelectric industry, provides a systematic approach to:

- identify acceptable performance levels for equipment throughout a projected plant lifetime.
- establish a least-cost plan for monitoring and achieving these performance levels.
- implement and continually update this plan.

Hydro plant machinery deteriorates with age and will eventually fail, principally due to thermal, electrical and mechanical degradation of insulation materials used in the windings and elsewhere, and erosion, corrosion and hence fatigue in turbine components. This is also true for the mechanical equipment and structures associated with a hydro plant, where climatic conditions and natural extreme events, such as floods and earthquakes, are often factors.

Traditionally, the owners or operators of hydro plants combat the effects of aging through a variety of operating and maintenance methodologies. Inevitably, after a long and successful, or short and unfortunate, operating lifetime, largely depending upon the capability of operating and maintenance practices, the condition or performance of the generating equipment reaches a crisis. Operating costs exceed revenues or generation ceases due to a major component failure. Depending on available resources and alternative generation sources, the response of the owners and operators to this crisis ranges from forced retirement of the plant, to life extension, modernization or site redevelopment. (See Figure 1-1.)

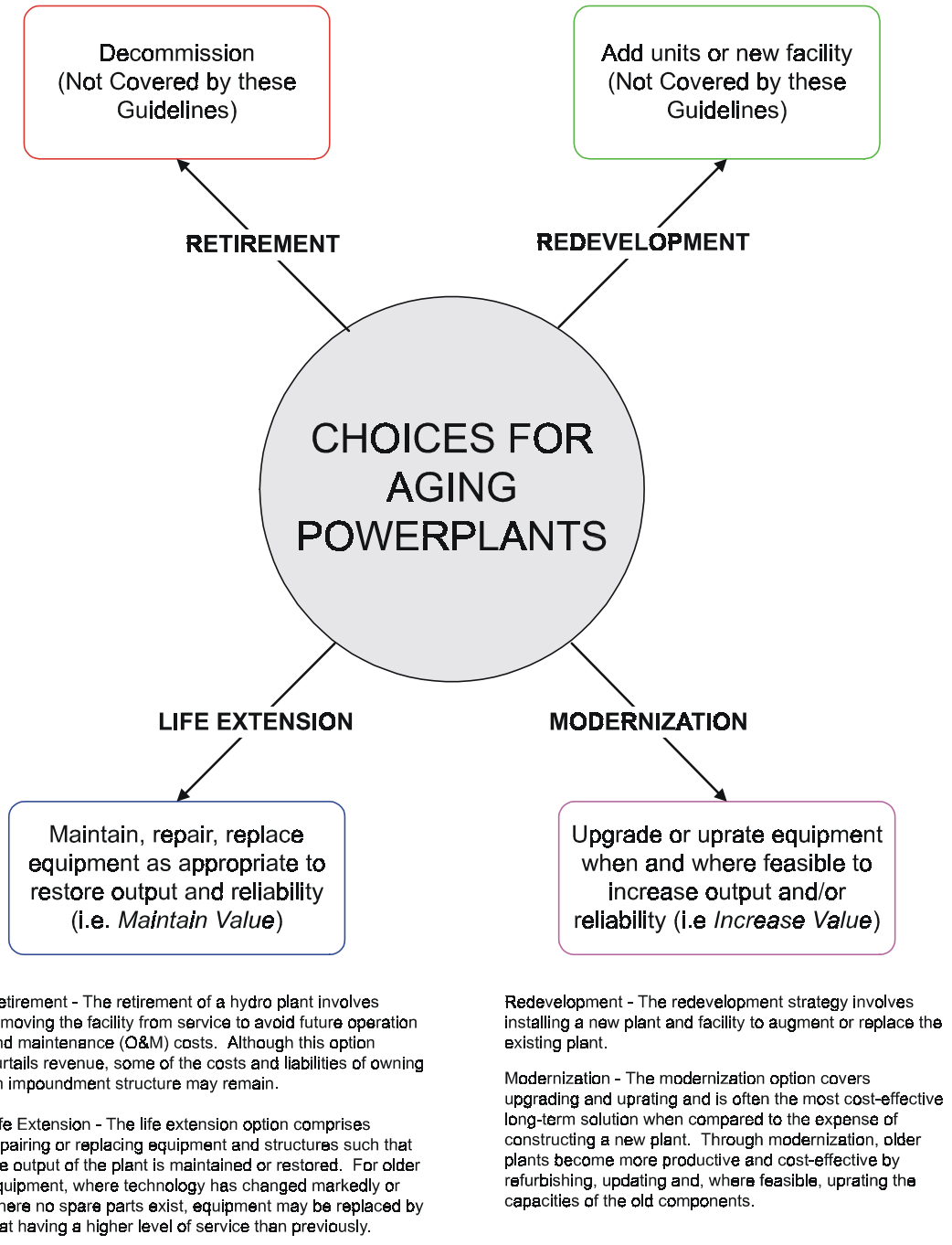

Decommission
(Not Covered by these Guidelines)
Add units or new facility
(Not Covered by these Guidelines)
RETIREMENT
REDEVELOPMENT
CHOICES FOR AGING POWERPLANTS
LIFE EXTENSION
MODERNIZATION
Maintain, repair, replace equipment as appropriate to restore output and reliability (i.e. *Maintain Value*)
Upgrade or uprate equipment when and where feasible to increase output and/or reliability (i.e *Increase Value*)
Retirement - The retirement of a hydro plant involves removing the facility from service to avoid future operation and maintenance (O&M) costs. Although this option curtails revenue, some of the costs and liabilities of owning an impoundment structure may remain.
Life Extension - The life extension option comprises repairing or replacing equipment and structures such that the output of the plant is maintained or restored. For older equipment, where technology has changed markedly or where no spare parts exist, equipment may be replaced by that having a higher level of service than previously.
Redevelopment - The redevelopment strategy involves installing a new plant and facility to augment or replace the existing plant.
Modernization - The modernization option covers upgrading and uprating and is often the most cost-effective long-term solution when compared to the expense of constructing a new plant. Through modernization, older plants become more productive and cost-effective by refurbishing, updating and, where feasible, uprating the capacities of the old components.

Figure 1-1
Options for the Future of Aging Powerplants

Deciding what to do and when to do it is often a dilemma for hydro plant owners. Short-term constraints, goals and special interests (technical and otherwise) may conflict with effective long-term planning. Additionally, economic, regulatory, safety and environmental factors can influence decisions on the future of hydro plants.

Outcomes that may be attained through a life extension or modernization program include:

- Maintaining output of electrical products and services.
- Reducing maintenance costs through new equipment or materials.
- Improving output and hence profitability, by replacement with more efficient equipment.
- Reducing operating costs through automation.
- Reducing risks against catastrophic failure, through assessment, surveillance and management processes.

As experienced personnel retire and leave utility companies, the need for systematic documentation of their knowledge and experience becomes apparent. These guidelines will help the present generation of utility owners and operators determine what options are available for the future of each plant and how to select and implement the optimum investments. They will cover both the options which increase revenue and those that manage risks and protect asset value.

1.2 Objectives and Scope of The Guidelines

The objectives of the guidelines are to provide a process based on knowledge and results rather than just data and information, to enable users to develop and implement commercially viable life extension and modernization improvements at their hydro plants.

The scope of the guidelines is to:

- Compile information on available and developing technologies for the maintenance, repair, life extension and modernization of hydro plant equipment and civil works.
- Develop tools to help utility personnel assess their needs for life extension and modernization in hydroelectric plants, and develop a cost-effective Life Extension and Modernization Plan.
- Provide technical data and information required for the implementation of the Life Extension and Modernization Plan.
- Identify licence implications of any upgrades.
- Identify improvements in technology that can decrease environmental impacts of hydro plants.
- Produce a resource tool for use by utility engineers and hydro personnel who may not have extensive experience in hydro plant life extension and modernization, but have thorough knowledge of hydro plant equipment and operations.
- Provide information for preparing a business case for implementing hydro plant modernization projects.

The guidelines provide methods to assess the condition of existing plant components, identify promising modernization alternatives and determine the design parameters, costs, and schedule requirements of these alternatives. Also included are approaches to evaluate alternatives and

implement the most cost-effective modernization. A case history will demonstrate the suggested process. Costs used are $ 1998 which can be adjusted to the current year by using the United States Bureau of Reclamation's Water and Power Construction Cost Index, which is published during the last month of each quarter in the *Engineering News Record*.

All aspects of the hydro plant are considered for life extension and modernization, including the typical structural, electrical and mechanical systems. The guidelines address conventional hydropower and pumped storage, except for some of the unique features of pumped storage.

Extending life and modernizing hydro plants can provide excellent and financially rewarding opportunities for taking advantage of state-of-the-art improvements. These are summarized in Appendix A and discussed in more detail in the technical volumes (Volumes 2 to 7).

The plant owner needs to be aware of applicable and current safety codes and standards during plant assessment and modernization activities.

Life extension and modernization of the plant may require amendment of its existing licence with the appropriate regulating agency, and historical preservation regulations may affect the modernization program.

This guideline contains an annotated bibliography of case histories, industry standards, recommended practices, and other guides. The list is extensive and comprehensive, providing a starting point for more detailed review of the life extension and modernization process.

1.3 Concepts

Life Cycle Management

Economic and environmental pressures are making investments in life extension and modernization of aging hydro plants realistic alternatives to the construction of new plant. Important in the assessment of the owner's system are the special attributes of hydro power and how they can be fully used in both the existing and future integrated electrical system. Equally important is a need for utility managers to focus on production excellence. Operating costs of the generating equipment, though probably already small, are often used as a measure of performance. A systematic multi-discipline procedure ensures that all potentially valuable options are included.

Life cycle management optimizes the use of equipment, water resources, staff and funds to guide expenditures and decisions. Issues such as licensing, environmental compliance and risk management are also taken into account.

Overall the process aligns plant activities, with regard to life extension and modernization, with market drivers, in order to:

- Maintain or improve dependability by monitoring existing performance and conditions and initiating action on the basis of commercial impact over a long-term planning horizon.
- Maintain sustainability by meeting compliance and regulatory requirements and managing risk.

- Improve flexibility by optimizing the product mix from the plant.
- Improve efficiency by modifying plant design.
- Improving profitability by identifying plant performance and value, and making investment decisions to meet corporate financial criteria.

To meet new market needs, new operating methods may be required. Present operation may be quite different from what was envisioned when the plant was originally designed (e.g. stop start operation to capture high value power markets).

Determining the cost of life extension and modernization options is an essential part of planning. Not all will be cost-effective. Some improvements, particularly those that mitigate against catastrophic events, may need to be made on the basis of reducing the risk of potentially enormous losses, without a clearly defined monetary benefit.

Life Extension

Life extension is the replacement of major plant components on a “like for like” basis as needed, thus extending the life of the entire hydro plant.

Each component of a hydro plant has an inherent “life” which depends on the component design, quality, safety factors, operational stress and stress cycles, type of material, corrosion resistance and installation. The operating life of components may be drastically reduced if maintenance has been insufficient, or if the plant operating conditions differ from the original design parameters. As an example, water quality deterioration can reduce the useful life of plant components from original expectations.

The useful life of the plant can be increased by rehabilitating the components to a like-new condition. This can be less costly than replacing equipment, since a large percentage of the existing components can be reused.

Hydro plants are inherently reliable and have high availability. Owners and operators are aware of the consequences of unplanned outages, and a priority in operating a plant is to maintain the availability of the plant’s systems. Some of the methods used by hydro operators to accomplish this goal include performing planned preventive maintenance, condition-based maintenance, reliability centred maintenance, providing redundant auxiliary systems and planning unit maintenance during periods of low power prices, but compatible with electric system requirements.

In some hydro plants, availability is affected by the condition of auxiliary equipment. Forced outages may be caused by minor system components such as belt drives, pumps, motors, electronic circuitry and electromechanical components. Problems caused by these minor components can be solved by repair, improvement or replacement and this is normally very cost-effective.

Hydro plants can be subject to risks that could have catastrophic consequences. Risk management can provide mitigation against catastrophic failure. Surveillance, testing, monitoring systems and diagnostic methods are now available to help predict, and avoid, catastrophic failures. Typically, the avoidance of a single major failure would repay the cost of these systems many times over.

Modernization

Modernization is essentially the integration of new components with existing to improve the overall plant and maximize value. Technology has improved since the plant was designed and built. Conditions may have changed and the economic drivers may be different to those which define the original development.

Categories of modernization activities, which improve the performance of the plant, are highlighted in the following box:

Increasing Plant Output: Ways to increase capacity and/or energy are found throughout the plant; they include increasing operating head by raising the reservoir level or lowering the tailwater levels and uprating or adding capacity through either physical or operational improvements. Reducing Losses: Reducing, or eliminating, losses which have developed over time often restores the capacity and efficiency of hydro plants to their original design levels. In some cases, improvements can be made that effectively increase capacity over the original level. Some typical methods used during plant modernization to reduce energy losses include repairing leaks and reducing seepage in structures, repairing/replacing seals, reducing hydraulic head loss, by optimizing water passage design and installing new, more efficient equipment.	Improving Operation: Improving the use of water can be achieved by using computerized models which incorporate plant characteristics, flow forecasts, outage schedules and other operating constraints to optimize generation dispatch. Reducing Operating and Maintenance Costs: Operation and Maintenance (O&M) costs can be reduced at the plant level in a number of ways. Supervisory control and automated data acquisition (SCADA) reduces many of the manual functions performed at older plants. Improved operational data assists in determining maintenance requirements and reducing forced outages. A move towards condition based maintenance can be coupled with replacing worn equipment and modern processes for maintenance management systems. Greater automation reduces requirements for operating staff and increases efficient use of equipment. Substantial returns can be identified, when evaluating modernization options, particularly where 24 hour staffed positions can be eliminated or reduced to single shift operation.

Need and Timing of Plant Investments

Existing hydro plants generally have low operating costs compared to the competition and, so long as the plant is in reasonable condition, life extension is usually cost-effective. Add to this the opportunities to increase output, either in direct power or support/ancillary services, and existing hydro plants are typically found to be a valuable asset.

There are some non-engineering issues, particularly licensing and environmental, which have to be considered and addressed. Sometimes this results in significant cost, either directly or through loss of generation.

Components of hydro plants typically show little sign of deterioration in the early stage of life. However, when exposed to the environment and operated under stressed conditions, they gradually begin to fail. While proper maintenance and operation can prolong component life, eventually there is a need for replacement.

Conversely, costs associated with the original investment and renewals decrease initially as the debt decreases with time, and then begin to rise in response to the need for overhauls and replacements. Gross output also tends to decline slightly over time as unit efficiency decreases with equipment aging. As components near the end of their useful lives, unit efficiency and forced outages begin to significantly reduce generation and net revenue. This can eventually result in operating losses.

It is inevitable that investments will be required in maintenance, repairs, replacement parts, and the upkeep of hydro plants. The question facing utilities is not ***if*** future investments will be necessary, but ***when*** to make the investment and ***how to*** maximize subsequent returns.

A utility needs to develop a strategy for the timing and extent of plant investments. This requires a balance between technical and risk considerations for the equipment and financial considerations on the value of the plant and the projected future value of capacity and energy.

Life Extension is a strategy which maintains or restores the hydro plant to its original condition. Equipment failures can result in the failure of additional components, with consequential damage, and the lead time to obtain replacement parts can extend the outage, possibly increasing generation losses. Moreover, major unexpected failures can require large investments in repair and upkeep of older plants, which may not be justified but which cannot be avoided once an emergency situation has occurred. In these cases, the optimal time for decision making has passed and it is too late for strategic planning and analysis.

The optimal time to make investments in an operating plant is difficult to determine. Since hydro plants are designed for specific hydrologic and topographic conditions, each plant is unique. Further, plants contain a wide variety of components from civil structures to electronics, whose lives vary. The quality of the original components, usage, and past component replacements also complicate the ability to predict plant life.

1.4 How to Use the Guidelines

The framework for screening plants, then choosing and proceeding with a life extension or modernization project is set out in:

1. Volume 1: Life Extension and Modernization of Hydroelectric Plants

2. Volumes 2 to 7, organized by type of equipment:

- Volume 2: Hydromechanical Equipment
- Volume 3: Electromechanical Equipment
- Volume 4: Auxiliary Mechanical Systems
- Volume 5: Auxiliary Electrical Systems
- Volume 6: Civil and Other Plant Components
- Volume 7: Protection, Control and Automation

Volume 1 presents a step-by-step method to identify plants for life extension and modernization. The user is then taken through the steps necessary to develop a life extension or modernization plan and to design project(s) for implementation. Volume 1 comprises:

Section 1: Introduction. Explains the needs, concepts, objectives and scope of the guide. The user will gain an understanding of what the guide contains, whether it will be applicable to the user's needs, and how to use the guide.

Section 2: Background. Discusses a utility's approach to life extension and modernization, including the policies and principles that need to be in place. Business considerations such as performance indicators, risk, environmental, commercial and estimating issues are also covered.

Section 3: Screening and Prioritization. This is the first step of the life extension and modernization process. The user obtains the necessary information about the utility and its hydro plants. In many cases this information will clearly justify proceeding directly to Section 4 and developing a life extension/modernization plan. Where it is uncertain, or prioritization is required, the user is led through the necessary steps of a desk study to screen, prioritize and rank their plants at a high level in terms of *most likely to yield benefit from life extension and modernization*.

Section 4: Life Extension and Modernization Plan. Focuses the user on individual plants which were ranked high (in need of improvement) in Section 3.0. This section shows how to gather pertinent information, and assess plant condition along with level and cost of service. Activities are forecast with associated timing and cash flow for life extension, and a 20 year life extension plan is prepared. Technical data for equipment and components will be extracted from Volumes 2 to 7 to support this assessment. Potential opportunities for modernization, based on information in Appendix B, are assessed and applied to the life extension plan as incremental improvements. The user is encouraged to align these opportunities with their utility's strategies for operations, maintenance, and workforce, risk and improved product portfolios. By evaluating opportunities, costs and benefits using a straightforward economic model, a modernization plan can be developed.

Section 5: Approach for Multi-Plant Portfolio. Outlines a process which could roll together the life extension and modernization plans for individual hydro plants, prepared in Section 4, to ensure that the benefits of owning a portfolio of plants are maximized. (The approach is outside the scope of these Guides, and this section only covers a discussion of processes.)

Section 6: Institutional and Regulatory Issues. Starts with the FERC licensing program and includes other permits and licenses applicable to users in the USA. The section then takes the user through the process to evaluate licence risk exposure and to develop a licensing strategy.

Section 7: Feasibility. Following selection of a life extension/modernization plan for a hydro plant, Section 7 takes the user through the analysis, tests and justification necessary to prove feasibility. Once again, Volumes 2 to 7 provide detailed component information to support this work.

Section 8: Project Definition and Implementation. Covers definition of the modernization work leading to project approval and implementation. Examples from Volumes 2 to 7 illustrate points and identify areas of success and others needing improvement. The guidelines provide knowledge to help the user implement the selected plan with confidence that the future benefits of life extension or modernization will be realized. Depending on the available internal engineering capabilities, implementation of the selected plan may require assistance from experts and consultants.

Annotated Bibliography: Case histories, reports of new technologies and processes, and other published papers provide supporting information and opportunities for further reading.

Appendix A: Covers new technologies and techniques which are presented under the same categories as Volumes 2 to 7. The Appendix provides only brief descriptions; the details are contained in Volumes 2 to 7.

Appendix B: Provide a background to modernization opportunities that can enhance the product portfolio of a hydro plant.

Appendix C: Provides an example to demonstrate the methods which are suggested in the guidelines. The case study is based on an actual modernization project, and takes the user through the steps in the guidelines to illustrate how they can be used.

Technical information from Volumes 2 to 7 is used as input to the life extension and modernization planning process and implementation of the selected option, as developed through Volume 1. Figures 1-2 and 1-3 shows the overall process, including integration of the seven volumes.

Table 1-1 shows the Table of Contents for Volume 1 as well as for Volumes 2 to 7.

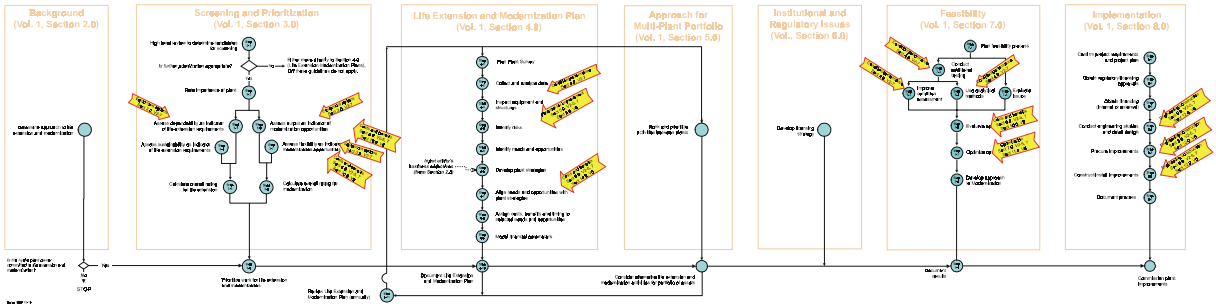


Figure 1-2
Overall Life Extension and Modernization Process (Vol. 1)

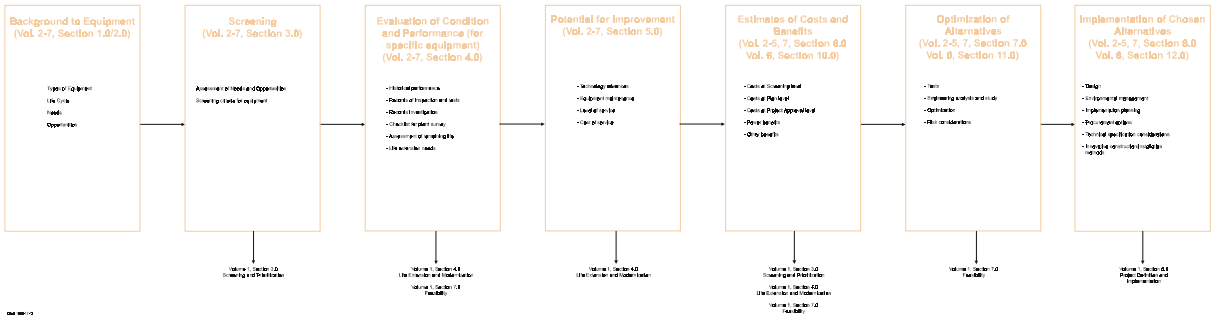


Figure 1-3
Overall Life Extension and Modernization Process (Volumes 2 to 7)

Table 1-1
Table of Contents for Volume 1 and Volumes 2 to 7

LIFE EXTENSION AND MODERNIZATION GUIDES
VOLUME 1

CONTENTS

Section | Subject | Page

DEFINITIONS

SYNOPSIS

1.0 INTRODUCTION
- 1.1 Need for Guidelines
- 1.2 Objectives and Scope of the Guidelines
- 1.3 Concepts
- 1.4 How to Use the Guidelines

2.0 BACKGROUND
- 2.1 Utility Approach to Life Extension and Modernization
- 2.2 Industrial-Owned or Non-Utility Plants
- 2.3 Business Considerations

3.0 SCREENING AND PRIORITIZATION
- 3.1 Identify Obvious Non-candidates for Screening
- 3.2 Rate Importance of Plant
- 3.3 Rate Dependability as Indicator of Life Extension Requirements
- 3.4 Rate Sustainability as Indicator of Life Extension Requirements
- 3.5 Calculate Overall Rating for Life Extension
- 3.6 Rate Output as Indicator of Modernization Opportunities
- 3.7 Rate Flexibility as Indicator of Modernization Opportunities
- 3.8 Calculate Overall Rating for Modernization
- 3.9 Prioritize Work for Life Extension or Modernization

4.0 LIFE EXTENSION AND MODERNIZATION PLAN
- 4.1 Plan Plant Survey
- 4.2 Collect and Analyze Data
- 4.3 Inspect Equipment and Structures
- 4.4 Identify Risks
- 4.5 Identify Needs and Opportunities
- 4.6 Develop Plant Strategies
- 4.7 Align Needs and Opportunities with Plant Strategies
- 4.8 Assign Costs, Benefits, and Timing to Selected Needs and Opportunities
- 4.9 Complete the Economic/Financial Evaluation
- 4.10 Document Life Extension and Modernization Plan
- 4.11 Review Life Extension and Modernization Plan

5.0 APPROACH FOR MULTI-PLANT PORTFOLIO
- 5.1 Purpose
- 5.2 Process
- 5.3 Implementing and Managing Investment Activities

6.0 INSTITUTIONAL AND REGULATORY ISSUES
- 6.1 Introduction
- 6.2 FERC Hydropower Licensing Program
- 6.3 Other Permits, Licences and Agreements
- 6.4 Typical Licensing Issues
- 6.5 Screening and Ranking Candidates
- 6.6 Developing a Licensing Plan
- 6.7 Glossary of Licensing Terms

7.0 FEASIBILITY
- 7.1 Plant Feasibility Process
- 7.2 Additional Testing
- 7.3 Improved Assessment of Condition
- 7.4 Use Analytical Methods
- 7.5 Evaluate Issues
- 7.6 Evaluate Options
- 7.7 Optimize Options
- 7.8 Develop Approach to Modernization
- 7.9 Document Results

8.0 PROJECT DEFINITION AND IMPLEMENTATION
- 8.1 Confirm Project Requirements and Project Plan
- 8.2 Obtain Regulatory/Licensing Approvals
- 8.3 Obtain Financing (Internal or External)
- 8.4 Conduct Engineering Studies and Detail Design
- 8.6 Construct/Install Improvements
- 8.7 Document Process

ANNOTATED BIBLIOGRAPHY

APPENDICES

Appendix
- A Relevant Technologies
- B Background to Modernization Opportunities
- C Case History

VOLUMES 2 to 7*

CONTENTS

Section | Subject | Page

1.0 INTRODUCTION AND SCOPE

2.0 BACKGROUND TO LIFE EXTENSION AND MODERNIZATION
- 2.1 Equipment
- 2.2 Systems
- 2.3 Components
- 2.4 Structures.....

3.0 SCREENING
- 3.1 Equipment
- 3.2 Systems
- 3.3 Components
- 3.4 Structures

4.0 EVALUATIONS OF CONDITION AND PERFORMANCE
- 4.1 Introduction
- 4.2 Description of Equipment
- 4.3 History of Maintenance, Performance and Major Repairs
- 4.4 Inspections and Tests
- 4.5 Operational Information (Records)
- 4.6 Evaluation of Design (Engineering Records)
- 4.7 Equipment Survey Checklists and Needs Summary
- 4.8 Assessment of Remaining Life
- 4.9 Required Activity for Life Extension
- 4.10 Timing and Schedule of Activities
- 4.11 Environmental Issues
- 4.12 Input to Life Extension Plan (Volume 1 Section 4.0)

5.0 POTENTIAL FOR IMPROVEMENTS
- 5.1 Advances in Technology
- 5.2 Equipment Maintenance
- 5.3 Level of Service
- 5.4 Cost of Service
- 5.5 Consideration of Alternative Improvements
- 5.6 Input to Modernization Plan (Volume 1, Section 4.0)

6.0 ESTIMATES OF COSTS AND BENEFITS
- 6.1 Introduction
- 6.2 Cost Estimates at the Screening Level
- 6.3 Cost Estimates for Life Extension and Modernization Plans
- 6.4 Cost Estimates at the Project Approval Stage
- 6.5 Power Benefits from Improvements
- 6.6 Other Benefits from Improvements
- 6.7 Input to Life Extension and Modernization Plans and Activities (Volume 1, Sections 4.0 and 6.0)

7.0 OPTIMIZATION OF ALTERNATIVES (FEASIBILITY)
- 7.1 Introduction
- 7.2 Testing
- 7.3 Engineering Studies
- 7.4 Optimization of Selected Modernization Activity
- 7.5 Risk Considerations for Modernization Activity
- 7.6 Sensitivity Analysis of Critical Parameters
- 7.7 Input to Life Extension and Modernization Plans (Volume 1, Section 6.0 and 7.0)

8.0 IMPLEMENTATION
- 8.1 Introduction
- 8.2 Design and Engineering Studies
- 8.3 Environmental Management Considerations
- 8.4 Implementation Planning
- 8.5 Procurement Options
- 8.6 Considerations for Technical Specifications
- 8.7 Innovative Methods of Construction

APPENDICES

Appendix
- A Literature Review
- B List of Suppliers

Note: * Volume 6 has four extra sections
- Dam Safety Evaluations
- Environmental Considerations
- Risk Considerations
- Life Extension Requirements

2
BACKGROUND

2.1 Utility Approach to Life Extension and Modernization

2.1.1 Organizations and Change

> "We trained very hard, but it seemed that everytime we were beginning to form up into teams we were re-organized. I was to learn later in life that we tend to meet any new situation by re-organizing and a wonderful method it can be for creating the illusion of progress while producing confusion, inefficiency and demoralization".
>
> Petronius 1st Century AD

Petronius may have been the first management consultant to reflect on organizational change. Yet the same issues are pertinent today.

To many hydro plant owners in the past, life extension and modernization was changing a piece of equipment that had failed or otherwise reached the end of its useful life with one that was more cost-effective or had higher output.

Today, life extension and modernization is a lot more complex. It is still about changing pieces of equipment, but also about changing operating methods, changing the numbers and roles of personnel and changing management approaches. This will take the hydro plant into the new millennium, an era of increasingly rapid change in new technology, computerization, market deregulation and licensing and environmental restrictions.

To be successful in life extension and modernization requires more than a knowledge of equipment. It requires a broad understanding of the entire hydro plant and how it fits into the portfolio of hydro plants, into the electric system and into the external environment.

It also requires an organization in which knowledge and learning can be focused on achieving the best results.

A key to success in any business is creating a climate to encourage the people within the organization to learn. To extend life and modernize an existing hydro plant, the organization has to identify, analyze and investigate options, and make decisions involving judgement, experience, choice and processes which are not linear.

This guide provides processes and information which can be put together in a number of ways. Different organizations could reach different conclusions and choices from the same information at the same plant. While these guidelines cannot prevent such variations, they can lead to better results in the hands of staff in a "learning organization".

Background

A learning organization continually expands its capacity to create its future by its positive and proactive response to change, and by improving its internal processes and learning from others outside the organization. It needs to have clear direction, efficient operations and positive team work. A learning organization is characterized by systems thinking, encouragement of personal vision, effective team learning and building shared vision.

The published literature contains many instances where an organization's commitment to learning, teamwork and continuous improvement has achieved superior results. Below are some extracts:

- Regular opportunities for communication between project team members were essential to the success of the modernization project. Weekly meetings included managers, supervisors, foremen, operators and trades.
- Work crews took part in discussions and how to resolve problems, this gave all a sense of ownership which bode well for the future.
- The organization has long provided an organizational climate to encourage suggestions and solutions to problems.
- The real gains of team work are an ability to work smarter.
- A fully integrated approach to planning provides a value based modernization program.
- An organization can foster learning by training, courses, use of consultants and staff exchanges.
- An organization's commitment to and capacity for learning can be no greater than that of its staff.
- Inter-relationships between models, processes, equipment and controls require a workplace environment which embraces and encourages innovation.
- The complexity of today's hydro plant and how it fits into the system, requires advanced thinking by those involved.
- The modernization project tapped into the intellectual capability of people at all levels, both as individuals and as groups.
- Modernization projects are different from these involving construction of new plants, they require:
  - overall knowledge of existing installation
  - foresight on performance
  - a holistic and long range perspective
- A key component of an organization's ability to learn, is their commitment to collecting, archiving and accessing information in a usable format.
- Success requires keeping knowledgeable staff for future modernization.
- A learning organization aligns the intellectual capital of its staff with the process required to improve asset value.

2.1.2 Policies and Principles

> "… the winners in the power production business will likely be those who invest to upgrade generation assets …" (Tony Armor, Director, Fossil Power Plants, EPRI, in Fossil Plant News, Spring 1997)

There are opportunities to close the gap between the desired and existing performance of generation assets, whether they are on the hydro or the fossil side of the power generating industry.

The 1980s and 1990s changed the lens through which many North American electric utilities view the future. Reduced load growth, forecasting uncertainty due to increased competition and deregulation, and growing concerns about the economic, environmental, and social effects of energy decisions encouraged changes in the way decisions are made.

An electric utility operates under the mandate (often an onerous responsibility) to supply reliable electrical energy to the consumer market. For the utility's corporate planners, life cycle management represents one of a number of alternative options to be considered in deciding where and how to allocate the utility's finite financial and technical resources in order to successfully fulfill their mandate. Conservation programs, load management programs, generation schemes, power purchase agreements, new generation developments and similar options compete with life cycle management for corporate commitments.

A corporate decision triggers development of the life cycle management (or asset) plans and the costs associated with them. This authorizes the means to establish technical criteria, objectives, schedules and resources for the collection and analysis of historical operating and maintenance data at each of the plants to be considered in the program.

Thus, any assessment of the needs and potential for hydro plant life extension and modernization requires a clear mandate from the utility, its management, directors and stakeholders.

This mandate will include:

- Policy towards life extension and modernization (the objectives).
- Principles on which the needs and opportunities will be determined (the criteria).
- Processes by which the needs and opportunities will be assessed (the program).

Individual utilities identify their own *policies* to suit their business needs.

Criteria reflect the *principles* on which modernization activities will be created, modelled, designed and implemented. Many criteria need to be considered and set before a modernization process is started. The remainder of this section provides some considerations for these.

The *processes* which help the user to select which plants to consider, how to develop a modernization plan and how to implement the necessary and attractive projects from it, form the balance of Volume 1, supported by Volumes 2 to 7.

In general, hydro plant owners are well advised to keep their assets aligned with industry standards so as to maximize their value. To do so will require some investment in improved equipment and/or technology. It will also require courage to make choices in times of uncertainty, and commitment to follow through with them.

2.1.3 Process Issues

Assumptions

Many issues need to be resolved prior to starting a life extension and modernization program. Some of the key ones are:

Methods of allocating costs, including cross company and overhead components.

- Methods of revenue allocation.
- Ways to define the value of products.
- Determination of the variable costs.
- Quality of records for operation, maintenance and production.
- Acceptance of a consistent Asset Register numbering system.
- Responsibilities for management and decision-making, at the plant and for operation and planning.
- Company requirements for justification of expenditure and budget allocation and limitations.
- Quality Assurance requirements for engineering or other groups.
- Company's requirements regarding finance and capital issues (depreciation, interest, discounted cash flow, taxes, etc.).
- Valuation process for power, ancillary services and any other products.

Approvals

Implementing and managing investment activities involves all processes between accepting a project in the work plan and placing the project in service. From a financial perspective, budgeting, obtaining financial approval and forecasting expenditures are important steps which have to be considered.

The financial approval process, in particular, is often very complex in large organizations. Managers have responsibility to the owners and stakeholders to ensure prudent and appropriate management of the strategic assets. Financial responsibility has to be balanced with flexibility to undertake projects in a timely fashion. An approval process which is heavy on control and procedure does not reflect the development of a skilled, flexible and trusted workforce. On the other hand, a culture change and skill development may be required for managers to be fully responsible and accountable for making business decisions. All affected parties may need to change to meet these goals.

Institutional and Regulatory Issues pertaining to FERC regulations and approvals are addressed in Section 6.

Other approvals, permits or licenses, external to the organization, are often required for water use, pollution control (e.g. oil spill containment, waste management) and plant decommissioning. Approvals may be required to ensure adequate and timely water diversion for other uses of the waterway (e.g. fish, irrigation, logging and recreation). In the case of independent power producers, a power purchase agreement may have to be negotiated or renewed.

If major construction is planned, approvals, permits or licenses are usually required for the following:

- Construction program.
- Noise abatement methods during construction (e.g. from trucks and construction equipment).
- Air pollution control methods during construction (e.g. dust from earth moving equipment and trucks).
- Importation of equipment and supplies.
- Transport of oversize and overweight loads (e.g. over roads, bridges, railway crossings, and under overhead lines).
- Water pollution control methods during construction (e.g. contaminated runoff from the site).

User Requirements

To complement the information in this Guideline, the following is required:

- Sufficient qualified personnel for investigations, inspections, tests and analyses.
- Detailed engineering information on current technologies related to the plant components being investigated.
- Engineering, operating, and maintenance records on candidate plants.
- Local cost information.
- Risk and reliability data.
- Relevant standards.
- Applicable laws and regulations relevant to safety, environment, licenses, permits, approvals.
- Knowledge of public and political issues.
- Apparatus necessary for inspections and tests.
- Company policies and procedures on financial evaluations.

2.1.4 New Approaches

Life extension and modernization of an existing hydro plant recognizes that improvements need to be made to equipment and structures. Generally, if the plant is greater than 10 years old, practical opportunities exist to extend its life and improve its performance. Changes in equipment, materials, efficiency, testing and surveillance methods and management processes, such as marketing ancillary services, provide the opportunities. With the abundance of information available on changes, it is often hard to determine which type of improvement is best for a plant, what it can achieve and how much it will cost.

As a first step, Appendix A of this Volume outlines the more recent fundamental changes that have taken place and continue to evolve. The Appendix does not attempt to provide detailed descriptions but to alert the reader to the alternatives available. These new approaches are covered in more detail in the Technical Volumes 2 to 7 dealing with each area and additional information can be obtained from the references in the annotated bibliography. Some of the items described are simply products of the improvement in computerization whilst others have been developed specifically with regard to hydro plant.

2.1.5 Resourcing and the Use of Consultants

One of the questions a utility faces when embarking on a life extension and modernization program is who will undertake the work.

While the utility will set the policies, define and in all probability manage the work, there are sometimes economic drivers that dictate that the core of the engineering be done by others. This may be simply that the utility does not maintain sufficient engineering staff to undertake the work or it may be that their priorities are elsewhere.

It is highly desirable that, where possible, maximum use is made of in-house staff, both for their existing experience and to familiarize them with the modernization process in the plant. These staff will then be knowledgeable for their ongoing role in maintaining and operating the newly modernized plant, as well as to provide ongoing technical expertise. Care has to be taken that the use of existing operation and maintenance staff does not result in the neglect of routine activities.

Where sufficient in-house resources are not available to undertake the life extension and modernization work, engineering consultants and/or manufacturers can be used. One of the key requirements is to have experienced and trained people, preferably in work of a similar nature. (Renovating, refurbishing and rehabilitating existing dams and hydro power plants have some characteristics which are different from the design and construction of new plants.)

There are good reasons to use the assistance of equipment manufacturers at various stages of the investigation, and they provide excellent advice in their own field. Naturally, manufacturers are in business to sell equipment and it may be difficult for them to recommend refurbishment rather than replacement. There is also the issue of potential contractual risk. It is advised that the excellence of manufacturer’s advice be combined with an independent viewpoint and an integrated process.

Many utilities have found that it is both cost-effective and technically beneficial to involve engineering consultants during a life cycle management program. They can provide:

- Speciality consulting to corporate planners on economic and financial criteria and models to be applied for generation planning studies and the selection of candidate plants for life cycle management program development.
- Review and analysis of specific equipment problems which may impact upon the residual life of a hydro plant and preparation of recommendations for least-cost corrective actions for inclusion in an overall life cycle management program.
- Technical audits of the effectiveness of a particular maintenance program or life cycle activity and recommendations for its enhancement.

The use of engineering consultants in assisting industrial-owned or non-utility hydro plant owners is discussed in the following section.

When choosing consulting engineers, there are distinct benefits of following a well defined process such as that set out in the American Society of Civil Engineers document: *Consulting Engineering: A Guide for the Engagement of Engineering Service, Manual No. 45.*

Unlike the purchase of equipment and construction, where cost is often the primary selection criteria, choosing a consultant is best based on the qualifications and experience of the company and its staff. A typical process includes:

- Preparing a scope of services containing the objective, scope of work, time schedule and collecting project information such as reports, drawings, and data.
- Issuing a Request for Proposals (RFP) to selected companies that can undertake the work.
- Evaluating the proposals using predetermined selection criteria.
- Negotiating a contract with the selected company.

Typical selection criteria for technical evaluation include:

- Company general experience, technical competence, management ability, QA program and client references in hydro plant modernization - 30%.
- Adequacy of the proposed work plan and approach in response to RFP and project scope of services - 20%.
- Qualifications, availability and experience of the personnel proposed for the assignment, including general experience in hydropower design and specialized experience in plant modernization - 50%.

The extent that hourly rates are considered in the consultant selection process will normally depend on the technical complexity of the assignment, impact on the project and level that the tasks can be defined. Price is often a less important selection factor for complex assignments or assignments lacking definitive work scopes, because the time required to complete the assignment may have a greater impact than labour rates. For those cases where the work scope cannot be clearly defined, compensation on a salary cost plus fixed fee basis may be appropriate.

2.2 Industry-Owned or Non-Utility Plants

When a comparison is made between the level and complexity of life extension and modernization activities being undertaken for industry-owned or non-utility hydro companies and the practices of most electric utilities, it is apparent that major differences exist in the corporate commitments to this type of program. Life cycle management principles and enhanced preventative, or predictive, maintenance programs are practised by the majority of utilities, while equivalent measures are in place for relatively few industry-owned plants and even fewer non-utility hydro plants. The main contributing factors for this difference appear to be corporate objectives and operating time frames used by the three types of hydro owners and the often vastly different levels of technical and financial resources.

Industry-Owned Hydro Plants

In the early 1900s, paper mills were often constructed adjacent to hydro development sites having sufficient capacity to satisfy the mill's energy requirements, along with those of the company town built for employees and their families. These mills were constructed before the availability of an electrical transmission system which could satisfy their energy needs. Similarly mining, mineral processing and refining companies developed captive power plants, often hydroelectric, and distribution networks to provide for their own requirements in the years before utility-based power systems were constructed. Today, many of these companies continue to operate their powerplants to supply some or all of their energy requirements although virtually all are also interconnected with utility power systems. Connection with the utility not only provides increased reliability and additional energy to satisfy both internal base and peak loads, but also, in some circumstances enables the industry to earn additional revenue through the supply of any surplus energy to the external system. However, from the corporate point of view, decisions on their own electrical generation are normally made based on their impact on industrial production. In general:

- The hydro plant competes with the main revenue-producing part of the company for funds. Energy supports the production of their primary revenue sources, and profitability benefits from minimizing the cost of power.
- Operating and maintenance processes serve the needs of the revenue-producing part of the company, as a priority.
- Company resources (management, engineering, maintenance facilities and personnel, etc.) are available to the hydro plant when the industrial needs are satisfied.
- Payback periods used in industry tend to be much shorter than those normally associated with hydro plants. Hence it is difficult to obtain capital for modernization.

Some industrial companies operate and maintain their hydro plant as separate profit centres, applying different economic criteria, or the plant operating and maintenance is contracted out. Others have sold their plants with a preferential power purchase agreement and tariff.

The scope of life cycle management for industry-owned generation is typically limited to condition assessments, and development of modernization, redevelopment or retirement options for plants which have reached the end of their economic operating life.

The role of an engineering consultant with an industrial owner can be similar to its role with utilities, in that the consultant is called upon to interface with an existing organization having in-house management, engineering, operating and maintenance capabilities. The difference is that industrial owners typically operate in much shorter economic time frames. Engineering consultants may be requested to carry out specific inspections and studies without any further input or role in the development of life cycle management options arising from their reports. Involvement by the consultant in a life extension or modernization activity often occurs after the criteria for the activity have been established and the decision made to proceed.

Non-Utility Hydro Plants

Non-utility hydro plants are owned by public groups (municipalities, conservation and agricultural authorities, native groups, etc.), or by private companies.

Increasing energy costs, the introduction of new technology and the support of public utilities for non-utility generation in recent years have all tended to promote the number and complexity of non-utility hydro plants. Life cycle management and enhanced maintenance would appear to be a natural consideration for owners and operators of this type of generation plant where production directly relates to revenue. However, the lack of financial and technical resources and expertise often results in the adoption of short-term goals to the detriment of long-term programs such as complete life cycle management.

Life cycle management opportunities vary over the plant life. During the initial plant design and construction, there are opportunities to incorporate features which will result in extended life and/or reduced operating and maintenance costs over the life of the plant. With small non-utility plants, these opportunities are often neglected in favour of minimal capital costs.

In the early years of the plant's operating life, the focus is typically on debugging the equipment and on establishing operating and maintenance procedures which will achieve the maximum revenue from the available water resources. All too often, this process leads to minimal expenditure on proper maintenance, rapid fixes for equipment and components and over-stressing of equipment.

Owners of small hydro plants find that it is usually uneconomic to retain sufficient full-time maintenance personnel to cover the range of skills required to maintain all plant equipment. Individual non-utility plants are often staffed by one person who is responsible for both plant operation and maintenance. In some cases, adjacent plants share maintenance staff. Contractors or manufacturers are used as needed for specialized maintenance work such as turbine/generator repair, machining/welding repair tasks, and electronics and computer hardware and software troubleshooting. Heavy maintenance tasks such as trash removal, brush cutting, road repair and snow clearing also generally involve outside contractors or casual labour. Depending upon the skills, dedication, accessibility and the cost of the operators and contractors available to a small hydro plant owner, the plant equipment and facilities may be maintained from a reasonable to an inadequate level. Minimizing costs and maximizing revenues, based on a "no frills" plant to start with, generally results in a gradual overall degradation of the plant and its performance.

As the plant ages, equipment outages and loss-producing events increase. The attention shifts to maintaining generation by responding to the crises of equipment failures, while combatting rising operating and maintenance costs in the face of falling plant performance and revenues. At this stage, opportunities may exist for timely and profitable modernization, or life extension considerations, if the owner is willing and able to allocate the necessary resources.

The engineering consultant's main role typically arises at the inception of a new project. After the plant is in operation, experience has shown that engineering consultants have little involvement in life cycle management activities of non-utility plants. The normal requests for engineering services tend to be in response to an equipment or facility failure crisis. In some cases, the consultant may be called upon to develop an optimum solution to the problem, rather than a quick repair or replacement.

Only when the plant has reached maturity and the end of its economic operation do most non-utility owners again involve engineering consultants. At this point, the consultant's role includes life cycle management studies and activities leading to recommendations for and perhaps implementation of life extension or modernization measures.

There may also be benefits for a consultant's involvement in the selling process of non-utility hydro plants. A prospective purchaser may gain confidence in the plant's value and forewarning of potential maintenance and operating expenses and risks by having a consultant assess the equipment condition and develop and estimate costs for a preliminary life cycle plan.

2.3 Business Considerations

2.3.1 Performance Indicators

Performance of a hydro plant can be considered in terms of its Level of Service and Cost of Service.

Level of Service is the performance requirement defined by the utility's customers, stakeholders and owners. It covers the quality and quantity of supply, the product range and services offered to meet the market requirements and the internal processes in place to manage, measure and improve these. This is within a safe, compliant and environmentally responsible framework.

Cost of Service is similar, though related to the entire cost of financing, operating, maintaining (producing) and improving the products and services.

An important concept to keep in mind is *existing level of service*. Proposed life extension activities will not in general, expand upon or increase the *products* offered by the facility. For example, if improvements in protection and control enable the plant to offer a new service such as voltage support, this is a modernization opportunity and the benefits and costs of this improvement need to be established.

Cost of Service is important from the perspective of planning for the entire portfolio of hydro plants. Although project economics at one plant may justify the life extension or modernization activity of a particular plant asset, there may be more attractive alternatives for obtaining the same or more *product* (i.e. energy, spinning reserve, voltage support etc.) from another plant with a lower cost of service.

The measurement of the level and cost of service at hydro plants used in this Guide is based on Performance Indicators for the following Descriptors:

- Dependability
- Sustainability
- Output
- Flexibility
- Importance/Profitability

Performance Indicators are used to assess individual equipment and structures as well as the entire hydro plant. They are the yardsticks which can indicate the condition and remaining service life of equipment and allow predictions of future maintenance and equipment replacement expenditures to be made. They also can be used to indicate opportunities for improvement.

Performance Indicators are used extensively in Sections 3 and 4 of this guide. Below is some background information.

Dependability

The concept of dependability represents a paradigm shift from the Reliability-Availability-Maintainability (RAM) concept, and is driven principally by increasing reliance upon electricity, telecommunications and information services as fundamental societal needs. This shift is dramatic and all-encompassing as shown below:

From:	**To**:
Conformance	Customer Satisfaction and Value Added
Lowest Cost	Life Cycle Cost
Statistics	Design Quality and Integrity; Risk Management
Standards	Best Practice

The changes illustrated above require owners to reassess their notions of acceptable plant performance and how it is determined.

Reliability

The notion of reliability evolved during the development of rockets for military use and for aerospace programs. The mathematical models for those applications were comparatively simple because repair was not a consideration. The rocket either succeeded or failed. With proper initial testing ("burning in") to identify and replace weak components ("infant mortalities") the mathematical expression for reliability is a simple exponential function of the specified operating time and Mean Time Between Failures (MTBF) (Mean Time to Failure (MTTF) when there is no repair).

For repairable equipment and structures the situation becomes more complex, particularly when the repairs can be further classified according to whether they are dictated by a failure or a planned maintenance program. In these situations the expression for reliability can be used to determine the probability of operating successfully (i.e. without failure) between successive planned maintenance periods.

In practice, the value of MTTF (if all repairs are corrective) or Mean Time to Unplanned Outage (MTTUO) (if some repairs are planned) is of more interest than the mathematical expression, because the characteristic of primary importance is Availability, which is sensitive to these terms. MTTUO is the appropriate term of power station repairs because they are invariably both planned and corrective.

In summary, the expression for Reliability is useful to predict the probability of operating successfully for a specified period of time. Reliability is related to Availability through the term MTTUO. Increasing the value of MTTUO increases Reliability and Availability.

At the plant level, Reliability is usually measured in terms of the number of forced (unplanned) outages. These are usually collected as System Disturbance Reports at the plant or control center.

For pumped storage and peaking plants, particularly where the plant is operated to profit from rapid changes in market prices, Starting Reliability is a key measure of performance. For these type of plants, Starting Reliability needs to be considered in assessing their performance.

Maintainability

The mathematical expression for Maintainability is usually exponential, but can be log-normal if spare parts are not readily available. The expression is a function of elapsed time and Mean Time to Repair (MTTR), (if all repairs are corrective), Mean Planned Outage Duration (MPOD) (for planned repairs), or Mean Unplanned Outage Duration (MUOD) (for corrective repairs when some repairs are planned), as applicable.

In practice, the value of MTTR, MPOD, or MUOD, as applicable, is of more interest than the mathematical expression, because the characteristic of primary importance is Availability Factor (AF), which is sensitive to these terms. MPOD and MUOD are the appropriate terms for power station repairs because they are invariably both planned and corrective.

The value of MPOD is generally determined by human decisions whereas the value of MUOD is generally a consequence of human decisions (or lack thereof). In effect there is a loose relation between MPOD and MUOD. For example, eliminating planned maintenance (i.e. reducing MPOD to zero) will almost certainly increase the value of MUOD. One of the objectives of a maintenance program is to minimize the sum of MUOD and MPOD. The recent trend towards predictive, or condition-based, maintenance may contribute to this objective.

In summary the expression for Maintainability is seldom used directly. However, Maintainability is related to Availability through the terms MPOD and MUOD. Decreasing the value of MPOD or MUOD increases Maintainability and Availability or AF.

In this Guide, Maintainability of hydro plants is assessed through their condition.

Availability

For long periods of time the mathematical expression for Availability or AF is simply the fraction of Period Hours (PH) that the unit is available for operation. The fraction increases as the sum of the planned and corrective repair times decrease. Availability or AF is a more useful term than Reliability or Maintainability for characterizing the hydro plant. Assuming no hydrological or regulatory constraints AF can be used together with unit loading to estimate the total energy generated during a specified period, and therefore the anticipated revenues.

Availability is a performance measure of reliability, and is measured in terms of the incapability of the hydro plant to produce power, measured over a period of time.

The term Commercial Availability is also used to measure the incapability of the hydro plant to produce power when, had it been available, the power and other services could have been sold.

Sustainability

Sustainability is assessed in terms of:

- licensing issues
- environmental compliance
- catastrophic risk issues

Sustainability is the ability to maintain the resource and hence its current profitability. Predictions are made of future situations, e.g. outcome of relicensing at expiry of current licence.

Output

Output is measured in terms of:

- Water utilization/Reservoir operation
- Generation

- Workforce
- Equipment

Information is gathered to determine the amount of the available water resource used for generation. This optimization of the resource has to be considered within licensing and regulatory limitations. This also includes balancing use of the reservoir between conflicting interests such as recreation, water supply, irrigation etc.

Information is also gathered to determine how efficiently and effectively the water that passes through the water conduits and turbines is used. Opportunities to increase equipment and unit efficiencies, change equipment ratings, reduce losses and increase operating heads are evaluated. This includes an assessment of equipment.

Plant workforce data is measured to determine if there are changes possible that can improve the efficiency and effectiveness of plant management.

Flexibility

Flexibility is measured in terms of the variety and level of products that a plant can provide to the system on demand.

Profitability/Importance

Profitability is measured once life cycle costs are known and revenue predicted.

Importance is an indicator of the impact of individual hydro plants in the overall portfolio. It is measured as the contribution of that plant as well as its criticality. Contribution is the amount of output compared with the entire portfolio of hydro plants. Criticality is the relative financial impact of a nominal 6 month forced outage. Other issues which are assessed by judgement include the importance of a plant to the system, based on its location and production of ancillary services.

2.3.2 Risk Issues

The ability to balance risks and potential gains is the very essence of decision-making in business.

Risk Consideration

Risk is the exposure to a hazardous situation that may happen in the future and that would result in unacceptable consequences. It is normally measured as the product of the probability of the hazardous event and its consequences in terms of loss of life and damage to property and the environment.

Society is generally risk averse, and therefore requires that the probabilities of events with high consequences be extremely low, particularly when exposure is involuntary. Moreover, modern societies generally require that the probabilities of events involving widespread loss of life (e.g. deaths due to the catastrophic failure of a large dam) be disproportionately lower than the probabilities of events involving individual loss of life (e.g. electrocution of a worker).

The probability of an event is usually based on the relative frequency of occurrence when considerable data exists. However, many risks are associated with comparatively rare events and there is some disagreement among experts on how to estimate the respective probabilities. Some prefer analytic techniques. Others are subjectivists and prefer to rely on opinions and beliefs to arrive at a sense of the probability. Usually existing codes address (sometimes implicitly) the probability of such rare events. However, users should consult a specialist if there is any doubt.

Specifically with regards to life extension and modernization projects, there are the risks associated with the design and implementation of works that involve applying new technology to ageing assets. This is particularly pertinent when these assets do not meet currently acceptable design standards or codes.

Many life extension or modernization projects are fragmented and completed over an extended period. The plant operating parameters as well as staff may change many times during this period. Thus continuity can be difficult and inherently pose risks.

To assist in addressing risk issues, three categories are considered:

Business Critical Risks

Those which have the potential to cause the business to fail.

The most obvious business critical risk is that associated with the catastrophic failure of equipment systems, power facilities or dams. These risks are often significant because when the plant was built, extreme loading (i.e. due to earthquakes, floods, winds, and snow) was often underestimated or excluded from the original design.

Regulatory requirements may dictate corrective action. Specialists are required to assess the risks.

Life Safety Risks

Those that could cause injury or death, but not necessarily jeopardize the business of the utility.

Life safety risks are typically associated with hazards due to fires, unsafe buildings, unsafe structures, unsafe equipment, unsafe controls, and unsafe working procedures. These risks are usually low and acceptable if design, manufacturing, construction and operation conform to applicable regulatory requirements (e.g. building codes, pressure vessel codes, OSHA requirements and statutory regulations). The extent to which current versions of regulatory requirements apply to old plant varies from one jurisdiction to another. These risks are often insurable providing the owner satisfies the conditions of the insurer.

Background

Applicable codes address (often implicity) life safety risks so it is usually unnecessary to estimate them. However, old hydro plants were designed and constructed in accordance with outdated versions of applicable codes or in some cases at a time when applicable codes did not exist. Given that the historical trend of codes and regulatory requirements has been toward lower risks, life safety risks in old hydro plants may be excessive by current standards. To address this issue some current codes specify the conditions under which an old plant must be upgraded. In the absence of relevant codes or other regulatory requirements the owner has to decide on the extent to which current codes apply to old hydro plants.

Financial Risks

Financial risks are typically associated with fires, environmental accidents and equipment failures. These risks are usually insurable providing the owner satisfies the conditions of the insurer. Other financial risks are design and construction related risks and failure to obtain the necessary regulatory approvals, licenses and permits.

Financial risks can generally be estimated using probabilities and the value of the corresponding financial losses from available data and relative frequencies. However, it must always be borne in mind that risks deal with the probability of a future occurrence and there is always an element of uncertainty in the analysis. The feasibility of corrective action can then be assessed by comparing the cost of correction and the benefit of the corresponding reduction of risk.

Risk Management

While detailed evaluation and management of risks is outside the scope of these guides, it is appropriate to briefly discuss an approach that can be followed by a hydro plant owner.

Business Critical Risks:

- Define the hazard associated with each risk.
- Evaluate the consequences if the hazard were to occur.
- Estimate the probability associated with the risk (either subjectively or analytically depending upon company policy and the opinions of the experts assessing the risk).
- Determine whether there are any applicable regulatory requirements (e.g. building codes) and act accordingly.
- Assuming the plant component conforms, or is made to conform, to regulatory requirements, obtain expert opinion on the acceptability of the risk.
- Assuming that the plant component conforms, or is made to conform, to regulatory requirements, accept or reject the risk pursuant to company policies and procedures for addressing such risks.

Life Safety Risks:

- Identify the regulatory requirements applicable to the plant for each risk.
- Determine the extent to which current versions of regulatory requirements apply to the plant as conditions precedent to re-licensing, and identify the associated deficiencies.
- Compare any additional requirements described above with those dictated by company policy, and identify the associated deficiencies.
- Assume that any significant work to extend the life of the plant or modernize the plant includes the requirements identified in the manner described above.

Financial risks:

- Define the hazard associated with each risk.
- Estimate the financial loss in the event that the hazard occurs.
- Estimate the annual probability associated with the risk.
- Estimate the cost of proposed remedial action to reduce the risk and the resulting reduced probability associated with the risk.
- Using the product of the annual probability decrement and the estimated financial loss as the benefit, and the cost of remedial action as the cost, calculate the appropriate financial indicator (e.g. benefit/cost ratio, internal rate of return) for a benefit extending for the estimated life of the plant.
- Compare the calculated value of the financial indicator to the threshold value considered acceptable by the company and act accordingly.

It is suggested that risks be tabulated, showing the category of risk (i.e. critical, life safety, financial), hazard, probability, analysis and any mitigating action. All risks and proposed contingency plans or mitigation strategies have to be reviewed by company management to ensure that they are understood and that the company accepts all risks that cannot be mitigated or insured.

2.3.3 Environmental Considerations

Hydro plants by their very nature create a disturbance to the natural flow of rivers. This can be an obstruction in the river or lake and/or a diversion of flows outside the natural watercourse.

For existing hydro plants there are often continuing efforts to reconcile environmental issues, particularly water use, between a variety of stakeholders. When a plant comes up for relicensing, or when a modernization option looks attractive enough to seek an amendment, these environment issues have to be addressed. This will be covered in more detail in Volume 6.

Changes concerning the environment may be the most significant that have occurred since the hydro plant was originally built. This includes changes due to:

- Licences and regulations
- Changed water or land use
- Changes in population demographics
- Knowledge of impacts of hydro plants on the environment

The environmental considerations addressed in this section will first cover existing environmental issues that affect hydro plant owners in general. The effect of changes, both for extending life and modernization will be covered as they relate the management, operation and technology. Finally, a synopsis of key initiatives being carried out across North America to address these issues is presented.

Existing Environmental Issues

Hydropower operations have significant impacts on natural, cultural and recreation resources. While some are beneficial, the concensus among environmental professionals is that the overall effect is usually adverse.

A survey of available literature identified four key environmental issues that affect existing hydro plants in North America:

- Fish passage
- Gas content (particularly DO) in turbine discharge
- Minimum flow
- Pollution

The USBR recently commissioned[1] a survey of its own plants as well as twelve other hydro plant operators in the U.S. and Canada on environmental issues. The results, which were compatible with others, are summarized in Table 2-1.

[1] Improving Environmental Compatibility in the USBR's Hydropower Program, A National Performance Review Analysis, M. Warton et al, Waterpower 97, Atlanta Georgia, August 1997.

Table 2-1
Major Environmental Issues Relating to Hydropower Operation (from M. Warton et al)

Effects of Hydropower Operation on Natural Resources

Primary adverse ecological effects attributed to hydropower development and operations are the loss or modification of riparian and aquatic habitats, nitrification and temperature fluctuations, and adverse effects on fish through entrapment, restricted passage, and restricted access to spawning habitat. Conversely, dams create opportunities for diversifying fish populations through creation of cool or cold water environments and substitution of lacustrine for riverine habitats.

Dams create physical barriers to the movement of fish. This obstacle poses a particularly difficult problem for anadromous species, such as salmon, that migrate from the sea up rivers to spawn in fresh water and on some native, non-anadromous species, such as the Colorado squawfish, that migrate long distances. A variety of structures (fish ladders, locks, and lifts) have been used with varying degrees of success to aid upstream migration by fish. Techniques are less developed for downstream passage, which involves timely movement of fish through the reservoir, protection against turbine entrapment, and passage around or over the dam.

In addition to restricting general fish movements, dams limit access by fish species to spawning habitat. Fragmentation of the river has also isolated subpopulations and restricted the gene flow within fish species. This confinement may weaken populations and increase their vulnerability to predation and disease.

Habitat modification also results in damage to fish and other species. Power production requires storage and rapid release of large quantities of water. Fluctuating water levels caused by these operations affect riparian and wetland habitats around reservoirs and downstream of dams. The nature of release flows not only affects water quantity, it changes the chemical composition and the physical characteristics of water below dams: mean temperatures and turbidity are often reduced and nutrients may be increased. These conditions change the environment of the river, which affects not only fish but also fish food organisms and surrounding vegetation. Changes in vegetative patterns influence the types and abundance of animals using the riparian zone. Shoreline and bank erosion caused by rapid fluctuations in water levels and high volume flows also contribute to habitat degradation. These conditions have contributed to the decline of many of the native fish species in western rivers.

Effects on Cultural Resources

Areas near water are rich sources for archaeological resources. Changing water levels and flows resulting from hydropower operations affect the resources in a number of ways. Entire sites or individual items can be moved from their original locations and redeposited in foreign locations by high water flows. In the same manner, soil from foreign locations can be deposited on top of sites, creating a false context for evaluating the resources. Individual items can be destroyed through violent water flows or erosion.

Erosion, which is exacerbated by fluctuating water levels, has a very detrimental effect on archaeological resources. Soil can be eroded from around objects and collapse items from one time period together with those from another era, which also creates a false context. Eroding soil at the shorelines exposes archaeological resources to looting and degradation from weather.

Dam facilities themselves that are associated with important historical and engineering patterns are protected as historic properties. Maintenance activities that include removing or replacing original equipment or other features of the plant can affect the historic integrity of the facility.

Effects on Recreation Resources

Hydropower projects produce prime water-related recreation. Reservoirs provide boating, fishing, water skiing, and swimming. The reaches of river below the dams also provide fishing, rafting, canoeing, and other stream-related recreation. Surrounding lands offer camping, picnicking, hiking, and environmental and cultural resource education and interpretation. Reservoir levels, release schedules, and instream flows can affect recreation quality.

Generally, reservoirs are managed by federal, state, or local governmental agencies to minimize adverse effects on recreational resources. In the aggregate, millions of people annually enjoy the recreational amenities at reservoirs.

Reservoir operations also create management challenges for the recreational program. Rapid rises in water levels downstream following a release can strand fishers in boats or flood campers. Diminished recreational opportunities can reduce visitation, which reduces revenues collected by the agency, concession providers, and local tourist businesses.

Recreational fishing is also affected by dam operations. Many of the non-native fish species that reproduce and thrive in the changed river conditions created by hydropower operations are those species (particularly trout) most favoured by sportsmen. This situation has at many times placed management for native threatened and endangered species in completion with management for recreational fish and game species. This conflict further complicates environmental decisions made by hydropower operators.

Other Environmental Considerations

Powerplants are industrial facilities and often require the use of hazardous or toxic materials, either in the generation equipment itself (e.g., polychlorinated biphenyls) or in the maintenance of equipment (e.g., cleaning, solvents, oils, etc.). Owners must comply with numerous legal requirements governing the use and disposal of such hazardous materials. Although non-compliance with these requirements involves significant penalties, the quantity and complexity of the wastes handled is relatively minimal. Therefore, this aspect constitutes a relatively minor part of environmental programs at the hydropower facilities.

Background

As part of the development of an Environmental Management System at BC Hydro, a listing was compiled of significant environment aspects relating to hydro plant operation and management. An ISO 14001 system requires this on an ongoing basis. Qualitative risk identification and ranking identified the aspects of hydro operation with potential for the highest impacts on the environment, these are highlighted in Table 2-2 below. From this information, targets have been set to meet Environmental Management Objectives, and activities have been defined to achieve these.

Table 2-2
Aspects of Hydro Plant Operation with Potential for Environmental Impacts

Area of Environmental Impacts	Aspects of Operations
Ecosystem Management (Wildlife, Aquatic, Terrestrial, Riparian)	• Increased volume of water spilled • Ramping down of units reducing tailwater levels • Fish entrainment through units • Fish entrainment through cooling water systems • Decreased volume of water spilled • Closing and opening intake gates • Changes in reservoir elevation • Operation of governor systems
Pollution Prevention and Waste Management	• Sump operation (oily wastes) • Fuel dispensing • Sump pump maintenance • Standby generator and fuel tank maintenance • Operation of gates • Operation of oil/water separator
Contractor Management	• Performance of inexperienced contractors • Lack of training
Social Issues	• Vandalism • Public access and safety
Air Quality	• Dust generation in drawdown zone • Debris disposal/burning

Technology Improvements

Where licence renewals or amendments are sought, there can be trade-offs available between modernization improvements to the plant and benefits to other stakeholders. This acknowledgement has helped drive the development of improvements in technology that can decrease environmental impacts. The most importance areas of technological improvements have been in water quality and fish passage.

Water Quality

Water Quality and Quantity issues cover:

- Dissolved gases
- Water temperature
- Sedimentation
- Spilling methods

Dissolved oxygen (DO) is a key issue in fish survival in certain parts of North America and elsewhere. Overall Total Gas Pressure (TGP) is an issue that is normally less critical but more widespread. Dissolved gases need to be in the right amounts and right proportions to enhance lacustrine and riverine environments. Changes to the natural balance occur due to passage of water through turbines and discharge facilities, such as spillways, conduits, valves etc. Air injection through the turbine is often an effective way to increase dissolved gases, as well as improve equipment operational performance. Air injection has been designed for inclusion in the turbine blades, turbine hubs and draft tubes. It can be injected under pressure or naturally vented. In all cases, the amount of air needs to be controlled and measured, and the impacts monitored.

Water temperature has a marked impact on downstream aquatic habitats due to variations in dissolved gases (CO_2 etc.) at different temperatures. There is a recognition of these effects on the diversity and size of fish populations. Withdrawal of water from different reservoir elevations can be used to select turbine discharge temperatures which enhance fisheries.

Sedimentation affects both the lacustrine (impoundment) and riverine environments. Means are sought to initially prevent the ingress of sediments to the reservoir. The sediments that do reach the dams, then have to be managed to minimize their passage through the turbine, which could cause damage to equipment. There are a number of designs of sediment basins and flushing techniques which can alleviate this problem.

Sediments can be flushed downstream, but care is taken to minimize the impact on the riverine environment. This can be achieved by mirroring the situation that existed prior to the dam being constructed and usually involves flushing during flood periods.

Operation of discharge facilities (spilling) can impact the composition of dissolved gases and fluctuations in reservoir and downstream river levels. Operating methods, rate of change of spill, choice of which gates are used, gate underflow or overflow, all can have different impacts.
A significant impact of flow/spill is the issue of fish stranding and salvage. This costly intervention can be prevented or minimized by altering operations, such as load balancing during critical periods in the life history of resident fish. This is particularly important during spawning periods when eggs and fry are at risk. To a lesser extent, zebra mussels can affect spill where they attach to spillway and intake equipment and structures.

Improvements in technology include:

- analytical methods to determine effects on aquatic environments.
- measurement and monitoring methods (flows, temperatures, TGP, etc.).
- improved turbine design or air injection methods.
- selected withdrawal techniques from different reservoir elevations, through physical changes to power intakes.
- improved discharge methods, such as inflatable rubber dams, adjustable slots in large gates.
- improved operation of multiple spillway gates.
- sediment removal methods to minimize flow through turbines.
- sediment passage across dams to prevent/limit accumulations.
- physical and chemical solutions to zebra mussel attaching to discharge facilities.
- alternative treatments for cooling water, necessary to prevent corrosion and limit organisms, but which pollutes downstream waterways.

Fish Passage

Downstream fish migration can be through the turbines, bypassing the units, over the spillway or through other discharge facilities.

Key factors influencing survival have been the basis for designs of new turbines. Investigations have provided a clearer understand of what mechanisms kill fish and how to design to minimize these.

The mechanical effects influencing survival include:

- number of turbine blades
- relative size of fish and turbine
- surface roughness
- fish location zone

The fluid effects influencing survival include:

- flow turbulence (efficient operation)
- pressure
- cavitation

Indirect effects include predation following injury or disorientation.

Advances in instrumentation for measurement, and computational fluid dynamics (CFD) have made it possible to improve predicted impacts on fish.

Some of the ways being considered for improvements (these can be different for different types of runner) include:

- reduce the number of blades and length of blade leading edge.
- maximize open space between blades and other structures.
- blunt leading edges and blades.
- smooth surfaces.
- high efficiency, low turbulence design.
- oil and grease reduction.
- lower running speeds.
- turbine design directs fish from runner tops towards hub.
- minimize gaps between fixed and moving parts of turbine.
- minimizing rate of pressure change.
- minimizing rate of velocity change (shear).
- selecting optimum operation ranges based on fish survival (often requiring advanced control systems).

In addition to the turbine, consideration is also being given for improvements at the intake, notably the trashracks. This includes angled trashrack bars for enhanced fish passage and means to prevent the build-up of trash which can impact the fish as they pass through the racks.

Downstream passage of fish to avoid the turbine can be achieved in a number of ways. These fall into three broad categories:

- reduce hydro plant operation during major downstream migration.
- screen the powerplant flows to prevent fish passage.
- attract/divert the fish to a bypass facility.

A number of screening mechanisms on the intakes or in the conduits themselves have been investigated, tested and in a number of installations, operate normally. The fish are prevented from entering the hydro plant flows and either bypassed directly back into the river or collected, sorted and trucked.

A number of methods to attract or divert the fish to a bypass facility have also been investigated, tested and, are now in place. These tend to use guides, louvres, netting, partial screens or hydro acoustic methods. This is sometimes coupled with reduced flows through the unit.

The bypass methods can be:

- the main spillway, sometimes with an overflow through a slot in the existing gate.
- retractable flashboards or rubber dam, small weirs.
- sluiceways, such as used for debris, or chutes.
- pipes.

Research and Development Activities

There are a number of Research and Development (R&D) initiatives that are considering ways to address and mitigate the environmental impacts of hydropower operation. These are being undertaken by dam owners and utilities themselves as well as by collaborative R&D groups, such as EPRI and the Canadian Electricity Association (CEA).

These initiatives apply to both ongoing operation as well as changes that may result from proposed modernization improvements.

The hydro industry has recognized for some time that some of the uses of water and land resources which it presently enjoys have been, are being or will be challenged. The industry has generally been proactive in seeking ways to mitigate negative impacts of hydro development on the environment.

Some of the key areas were summarized in a 1996/97 review[2] of ongoing and planned R&D activities associated with hydropower.

The information in this report is a solid foundation for further R&D activities and for coordination of initiatives between government and industry.

The R&D projects were grouped into the following 8 categories:

- Fish passage, behaviour and response
- Turbine related projects
- Monitoring tool development
- Hydrology
- Water quality
- Dam safety
- Operations and maintenance
- Water resources management

The projects listed are not exclusive, many others are being undertaken by individual utilities and hydro plant owners as they work to relicense their projects. However, the coverage is believed to capture all the main categories and the significant activities within them.

A summary of the review is shown in Table 2-3.

[2] This review was supported by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, under DOE Idaho Office Contract DE-AC07-941D13223, and is summarized in “Hydropower R&C Coordination”, by P.A. Brookshier et al in Water Power 97.

Table 2-3
Hydropower R&D Projects (from P.A. Brookshier et al)

Fish Passage, Behaviour, and Response

The projects in this category include: (a) design and evaluation of new passage technologies, (b) design and evaluation of screening technologies to keep fish from entrainment in water diversions (not necessarily associated with hydropower production), (c) studies of fish movements and behaviour in relation to dams and passage technologies, (d) field and modelling studies of fish habitat, and (e) fish physiology studies of the effects of turbine entrainment and passage technologies.

Site-specific studies of turbine mortality and injury are included in the turbine-related projects category. Many of the fish passage, behaviour, and response projects are also categorized with monitoring tool development and turbine-related projects. Behavioural studies are under way for several species.

Funds to install new passage facilities may often equal or exceed the cost of associated research.

Turbine-Related Projects

Turbine-related projects focus mostly on modifying hydropower turbines to reduce fish injury and mortality without compromising power production efficiency. Some are directed at improving the water quality associated with turbine discharges. Turbine-related projects include: (a) engineering design and testing of physical models, (b) data collection, (c) new monitoring tools, (d) improved equipment both for power generation and fish monitoring; and (e) guidelines for fish entrainment studies.

Monitoring fish mortality and injury from turbine passage is a significant element of many projects, as is monitoring pressure and flow conditions that the fish are subjected to during turbine passage.

Turbine research expenditures are much less than costs associated with installation of new or rehabilitated turbines. Some research into improved designs and operations for fish are part of much larger expenditures for turbine rehabilitation.

Monitoring Tool Development Projects

New monitoring equipment and systems are needed to better understand what happens to fish during turbine passage and around other passageways. To design turbines with reduced injury and mortality, and effective passage technologies, techniques are needed to identify types of fish and their distribution, as well as pressure and flow conditions they are exposed to. Computer technology advancements provide opportunities to develop new systems to monitor the condition and performance of turbines and associated equipment. Monitoring tool development projects include: (a) equipment and methods to monitor conditions and observe fish passage through turbines, (b) techniques to distinguish fish species and races, (c) methods to evaluate flow conditions around fish screens, and (d) equipment and methods to evaluate performance of turbines, and (e) methods to monitor water quality in large water systems.

Hydrology Projects

All hydrology projects identified for this report involve development of software to provide more timely and accurate information on weather and/or river flow conditions. This type of information is important to optimize hydropower operations.

Water Quality Projects

Recent attention has been directed at improving water quality, both within reservoirs and downstream of dams, by making operational and structural changes. Although impacts to aquatic life caused by changes in some conventional water quality parameters, such as dissolved oxygen and temperature, are fairly well understood, others, like metals and other toxic pollutants are not. More cost-effective methods are needed to improve dissolved oxygen discharges at hydropower facilities, water quality in reservoirs, and desalination. Gas saturation is a major issue in the Pacific Northwest. Projects to improve water quality include: (a) engineering design, (b) computer modelling, (c) development of monitoring tools for large reservoirs, and (d) development of desalination technologies for waste supply and water treatment. Most of the modelling work involves modifying existing models for humid, eastern reservoirs to arid, high-elevation western conditions.

Dam Safety Projects

Federal and State dam safety programs have identified many dams with hydrologic deficiencies. In some cases these deficiencies are probably real and require structural or operational changes; in other cases they may be a result of overly conservative analytical techniques that do not accurately reflect site conditions. Better tools for understanding and analyzing dam safety problems, so that cost-effective solutions can be implemented, are the focus of dam safety projects identified in the report. These projects include: (a) software development, and (b) physical model testing.

Operations and Maintenance (O&M) Projects

Attention to O&M is a high priority for hydropower operators. Advancements in computer technology have led to new opportunities to develop new tools and methods for O&M. Increased attention toward protecting fish and other environmental resources make evaluation and change of standard practices a necessity. O&M projects include: (a) improving methods to identify and address specific maintenance problems, and (b) developing software applications to optimize O&M. Some projects are directed at identifying environmentally acceptable methods.

Water Resources Management Projects

The increased attention to protect fish and other environmental resources/values while relicensing hydropower facilities, has led to new ways to approach relicensing processes and hydropower operations. The water resource management projects identified include: (a) tools for public involvement in hydropower licensing activities, and (b) tools to reduce costs of meeting fishery objectives.

2.3.4 Commercial Considerations

Parts of a Typical Contract

The parts of a sample contract for engineering works are described below. Note that contracts may contain other parts as well, or may be arranged in a different way, depending upon the policy of the owner.

Contract Agreement

The contract agreement typically contains the following:

- A statement of agreement between the owner and the contractor(s) to execute the work specified under the conditions specified in the contract.
- Identification of the contract documents.
- Relationship between the owner and the contractor(s).
- The contract price and terms of payment.
- The conditions precedent to the execution of the contract, or the effective date of the contract.
- Representations and warranties.
- Assignments.
- Appendices containing additional requirements as necessary.

Letter of Acceptance

The letter of acceptance is a letter from the owner to the contractor accepting the tender or revised tender, as appropriate.

General Conditions

The general conditions typically specify the commercial requirements of the contract, including, but not limited to, the following:

- The obligations, authority, and remedies of the parties to the contract
- Payment terms
- Penalties
- Insurance requirements
- The protocol for communications between the parties

Most companies have a standard set of general conditions. There are also models of general conditions available commercially.

Particular Conditions

The particular conditions modify or extend the general conditions for the particular application.

Specifications

The specifications contain the scope and requirements of the work.

Drawings

Drawings are provided as part of the specifications.

Bills of Quantities

The owner often provides bills of quantities as part of the invitation to tender to facilitate the evaluation of tenders. Bills of quantities are included in contracts to facilitate the measurement of progress for the purpose of interim payments. Bills of quantities are important to re-measurement contracts but may be unnecessary in other types of contracts.

Types of Contracts

In the context of financing, or risk, there are generally four types of contracts as follows.

Cost Reimbursable Contract (Cost Plus)

In this type of contract the owner pays the contractor for the actual cost of the work plus an additional amount representing the agreed profit.

The owner assumes most of the risk in this type of contract. Moreover the owner usually must survey the quality and quantity of work very closely to assure that the work is sufficient, of acceptable quality, and performed expeditiously.

This type of contract is seldom used now.

Re-measurement Contract

In this type of contract re-measurement of work is compared to bill of quantities in the contract for evaluating the final contract price. Risk in this type of contract is more evenly divided between the owner and contractor(s).

This type of contract is popular for civil works where the quantities of work are difficult to estimate accurately. Sometimes the contract will include provisional sums to address those parts of the works for which at the time of invitation of tender, the design is not yet fully developed or a decision to proceed has not yet been made.

Fixed Price Contract

In this type of contract the contractor agrees to do the required work for a fixed price.

The contractor assumes most of the risk in this type of contract.

This type of contract is popular for electrical and mechanical works where the quantities of work can be estimated accurately. It is also popular where the owner prefers to avoid the uncertainty of the contract cost. Note, however, that despite the fixed price, there are a number of situations where the contractor may be entitled to extra payments. As with the re-measurement contract the fixed price contract may include provisional sums.

Turnkey Contract

In this type of contract the contractor agrees to design, procure, manage and implement the work for a fixed price. The contractor assumes most of the risk.

The contractor agrees to undertake the work and deliver the completed project to meet performance specifications. These are set by the owner as performance criteria to be met. The means by which the contractor undertakes the work is generally at their discretion, with payment based on satisfying the performance criteria. As risks are transferred to the contractor, who also designs, procures and manages the project, costs can be higher. However, this increase can often be offset by innovative construction methods and competition in the bidding process. On the owner's side, engineering and management costs are sharply reduced. A prime considering in the setting of performance criteria relates to long-term maintainability, quality and durability.

Types of Technical Specifications

Technical specifications can contain considerable detail or simply define the required performance. Most specifications are somewhere between these two extremes.

Specifying considerable detail assures that the works will be what the owner wants, tends to avoid previous problems experienced by the owner, and facilitates control of the work. The disadvantages of specifying details are that the owner assumes more technical risk, the possibility of innovation is limited and the price and risk of error by the contractor is usually greater.

The converse is normally the case when specifying performance. However, the choice is made by the plant owner based on the nature of the works, price and risk.

Arranging Contracts to Limit Risk or Price

Owners can arrange contracts by product (e.g. dam, powerhouse and turbine), by project function (e.g. design, supply, installation and construction), or by a combination of these (including one contract for the entire plant).

When owners want to minimize their risk, they can select a fixed price contract with a performance specification and maintenance contract for the entire plant.

When owners want to minimize contract price, they can select separate contracts for various project components such as engineering, site supervision, supply of products, installation, site development, and civil works. In such cases owners can supervise construction and installation, or engage the services of an engineering firm for that purpose.

2.3.5 Estimating Considerations

Cost estimating is an integral part of the effective planning, design and construction of hydro plant modernization. Selection and justification of projects that involve substantial funding requirements, refinement and optimization of design, purchase of permanent equipment and the provision of essential construction services have to be made on the basis of sound economic decisions.

Cost estimates are used to:

- analyze and compare alternatives and evaluate feasibility.
- provide a long-term forecast of the financial viability of the plant.
- prepare long-term plans for modernization.
- provide information necessary for the preparation of project approval.
- monitor construction costs.
- provide workflow schedules and information for staffing and manpower requirements.
- provide information on request to outside licensing agencies, e.g. FERC.
- provide a basis to assess and analyze tenders for construction and/or equipment supply and install contracts.
- evaluate construction design changes.
- provide replacement cost evaluations of existing plant for financial, taxation and retirement review purposes.

Types of Estimates

The types of estimates required for the main phases of project development are shown below:

	Type of Estimate
Planning Phase	• Overview • Feasibility
Final Design and Construction Phase	• Design and Project Approval • Engineer's Estimate

Overview Estimates

Overview estimates are one of the earliest types prepared, possible for a number of hydro plants and alternative layouts. Estimated costs in this Guide are derived from cost curves and/or experience on similar projects. Very preliminary assessments of environmental and social impacts are included. These cost estimates are considered very approximate.

Feasibility Estimates

Feasibility estimates are based on sketches and drawings showing significant project details and dimensions. Several alternatives may be examined at this stage concluding with a recommended selection and potential preferred arrangement(s). Regulatory requirements, environmental and social impacts are studied systematically but not in exhaustive detail; the order of magnitude of benefits and losses are stated. An adequate contingency allowance is included.

Design Estimates

Design estimates involve refinement and optimization studies of a single project leading to a well defined arrangement of structures and major equipment. Major equipment costs are obtained from suppliers and cost estimates of all major items are prepared. Detailed construction planning studies are prepared to confirm the project schedule and identify critical activities. Sequences and selections of contract packaging are made. Environmental mitigation/compensation costs estimates are made at this stage; benefits and losses are determined in more detail.

Engineer's Estimates

Engineer's Estimates are the most detailed type of estimate required to be prepared.

The methods and procedures used to prepare Engineer's Estimates follows those of major contractors and in particular those of the Morrison-Knudson (MK) Company of Boise, Idaho, USA primarily because their methods are well detailed in Handbook of Construction

Management and Organization published by Van Nostrand Reinhold Company and edited by J.B. Bonny and Joseph P. Frein, both former senior officers of Morrison-Knudson. Chapter 14 of this book entitled “Cost Estimating for Lump-Sum and Unit-Price Contracts” is cited as a reference for preparing contractor type estimates.

Estimating Techniques

In the preparation of cost estimates the degree to which specific estimating techniques are employed depends on the nature of the work, the level of available design detail, and on the type of estimate and corresponding level of accuracy required. The following techniques are commonly employed for hydro plant modernization.

Ask Someone Who Knows - Typical examples include obtaining budget estimate component costs from existing records, suppliers and contractors.

Parametric Estimating - This technique provides a means of pricing items by comparison to known historic costs at a general level. It is useful for pricing items during early study stages with incomplete information. Examples of parameter costing are the total cost of a building expressed on the basis of a per square metre of floor area, or the cost of construction services, contingencies, or engineering as a percentage of related direct construction costs.

Historical Pricing - This technique utilizes cost indices available from external sources and/or generated internally by the utility, applied to historical tender prices and/or lump sums or actual unit prices to establish current estimated costs of civil work and/or electrical and mechanical equipment installations. This technique works well for larger and routine work at Overview stage but may be unsuitable for small and complex rehabilitation project involving unique construction methods or sporadic resource requirements.

Estimated Direct Costs Plus Indirect and Margin Percentage - This technique is similar to (e) below for “Detailed Contractor-Type Estimates” except that the detailed estimate is only carried to the contractor’s direct cost level. Indirect costs and margin are included by application of an appropriate percentage mark-ups rather than by detailed estimating.

Detailed Contractor Type - This technique uses first principle contractor-type estimating procedures to establish the contractor’s direct, indirect and margin costs. It is based on detailed quantity take-offs, planning and scheduling of construction operations and work methods to meet schedule dates, establishing and pricing the various resources for various estimate operations for direct, indirect and margin cost groups and as an unassembled estimate and then appropriately combining them as an assembled estimate to arrive at required unit prices. Engineer’s Estimates are usually prepared using this technique.

Estimating Contingencies

A sliding scale of contingencies for varying types of estimate, is given on Table 2-4. These contingencies cover potential costs not specifically identified during the cost estimating process, but which can be expected to occur.

Table 2-4
Hydro Modernization Projects - Construction Costs Estimates - Guidelines for Contingencies

Civil Contingencies (±)	Type of Study	
35%		
30%	OVERVIEW 20% - 35%	Based on sketches of major project features, showing general outlines and dimensions of dams, tunnels, penstocks, powerhouse, equipment etc. Costs derived from cost curves and experience on similar projects.
25%		
20%	FEASIBILITY 17.5% - 25%	Based on sketches and drawings of major features, showing some detailed dimensions. Several alternatives investigated briefly. Some optimization done. Costing generally similar to above, except carried out in more detail.
15%	DESIGN 12.5% - 20%	Based on more detailed drawings of major features. Many alternatives investigated and optimization of features carried out. Detailed cost estimates made of major items.
10%		

Note: Contingencies for mechanical and electrical equipment normally in the range of ± 7.5% to 20%.

Estimating Procedures

A standard procedure is applicable when:

- Good applicable historical cost data exists.
- The estimate relies on significant input from a trusted third party.
- Construction and installation methods are straightforward.
- Detailed estimates are not required and the consequences of an inaccurate estimate are acceptable.
- The value of the work is generally less than $1 million.

A flowchart for the procedure is given in Figure 2-1 below.

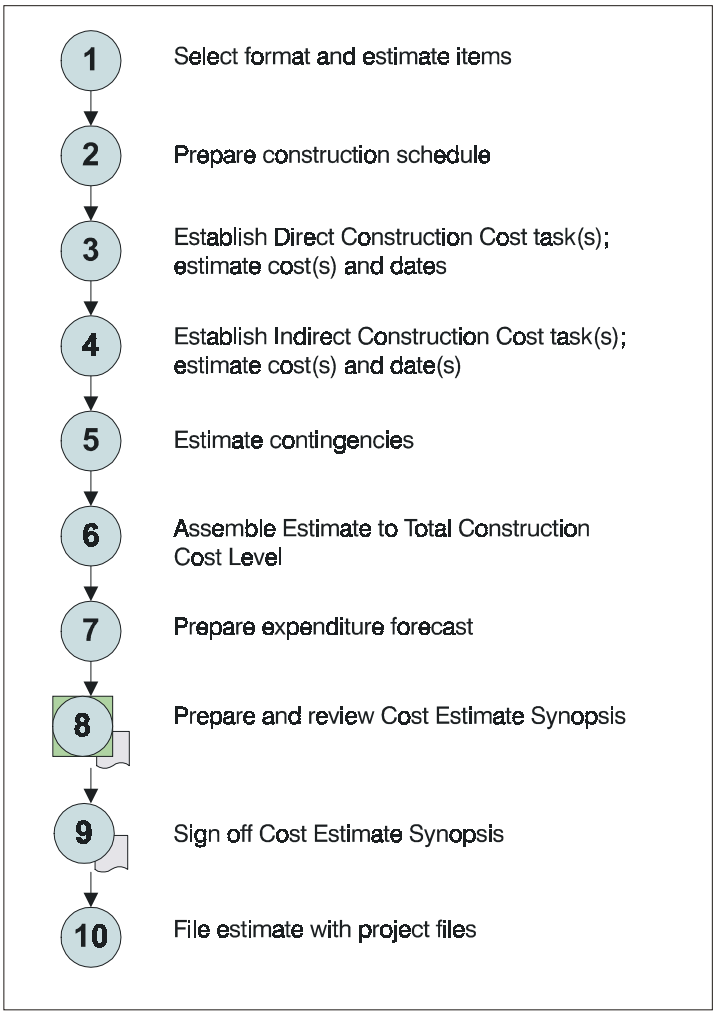


Figure 2-1
Project Cost Estimates and Schedules (Standard Procedure)

3
SCREENING AND PRIORITIZATION

Hydro plant owners face many choices and decisions around the ongoing management of their assets. Of paramount importance is whether the plant is meeting its stated objectives in terms of level of service and cost of service. Coupled with this are decisions on what needs to be done to restore or maintain these levels and what could be done to improve them.

In general, it is considered prudent to screen and prioritize all plants. However, for some plants it may be quite appropriate to move directly to Section 4 and develop a life extension and modernization plan. Alternatively the plant may clearly not be a candidate for either life extension or modernization. Where decisions are not straightforward and where initial, compatible information is required, this screening and prioritization process is appropriate.

Figure 3-1 shows a process for screening and prioritization, which can typically be performed in a day or so for each plant by using available information and interviewing key personnel.

Screening and prioritization starts with a rating process, using ***indicators*** as shown in each step. The indicators provide a means of measurement (in qualitative terms) of the five descriptors for each hydro plant. The first descriptor, Importance, covers both life extension (needs) and modernization (opportunities). Dependability and Sustainability cover needs. Output and Flexibility cover opportunities.

The ratings will allow input to the decision on whether to pursue a life extension and modernization process (Section 4) and will help prioritize work in order of importance.

An example of the use of the screening process is given in the Case History contained in Appendix C of this volume.

Screening for Life Extension

Each component of a hydro plant has an inherent life, which can be drastically reduced if maintenance has been insufficient, or if the plant operating conditions differ from the original design parameters.

Situations that drive decisions on life extension include:

- Plant has overall profitability (either assumed or proven).
- Plant and equipment has declining availability and failures of major equipment.
- Maintenance costs are increasing.

- Some components/equipment/structures require restoration.
- Little opportunity apparently available to increase output of products or services.
- Product unit costs are high.
- Plant generally meets utility's policy and criteria for continued operation (importance, stakeholder interests, etc.).
- Licensing and other regulatory/environment issues allow continued operation.

Two fundamental questions have to be answered in assessing the needs for life extension:

- What needs to be done? (Indicated by dependability and sustainability)
- What is the priority to undertake work? (Indicated by importance)

Screening for Modernization

Modernization of hydro plants achieves improvements in two areas; output and flexibility. Although modernization may require significant investment, it will technically improve the hydro plant and yield an economic return on the investment.

Situations that drive decisions on modernization include:

- Plant has overall profitability (either assumed or proven), or
- Plant would change from non-profitable to profitable with modernization.
- Likely opportunities are available to improve performance.
- Market needs/values change.
- Likely opportunities are available to increase output of products and services, and/or to automate plant.
- Opportunity to improve product mix.
- Availability of finance.
- Modernization of plant generally meets utility's policy and criteria (importance, payback, stakeholder interests, etc.).
- Licensing and other regulatory/environmental issues would allow modernization (potential changed operation).

The two fundamental questions which are asked in assessing the attractiveness of modernization are:

- What opportunities exist? What can be done? (Improvements in output and flexibility)
- What is the priority of the work? (Improvements in importance)

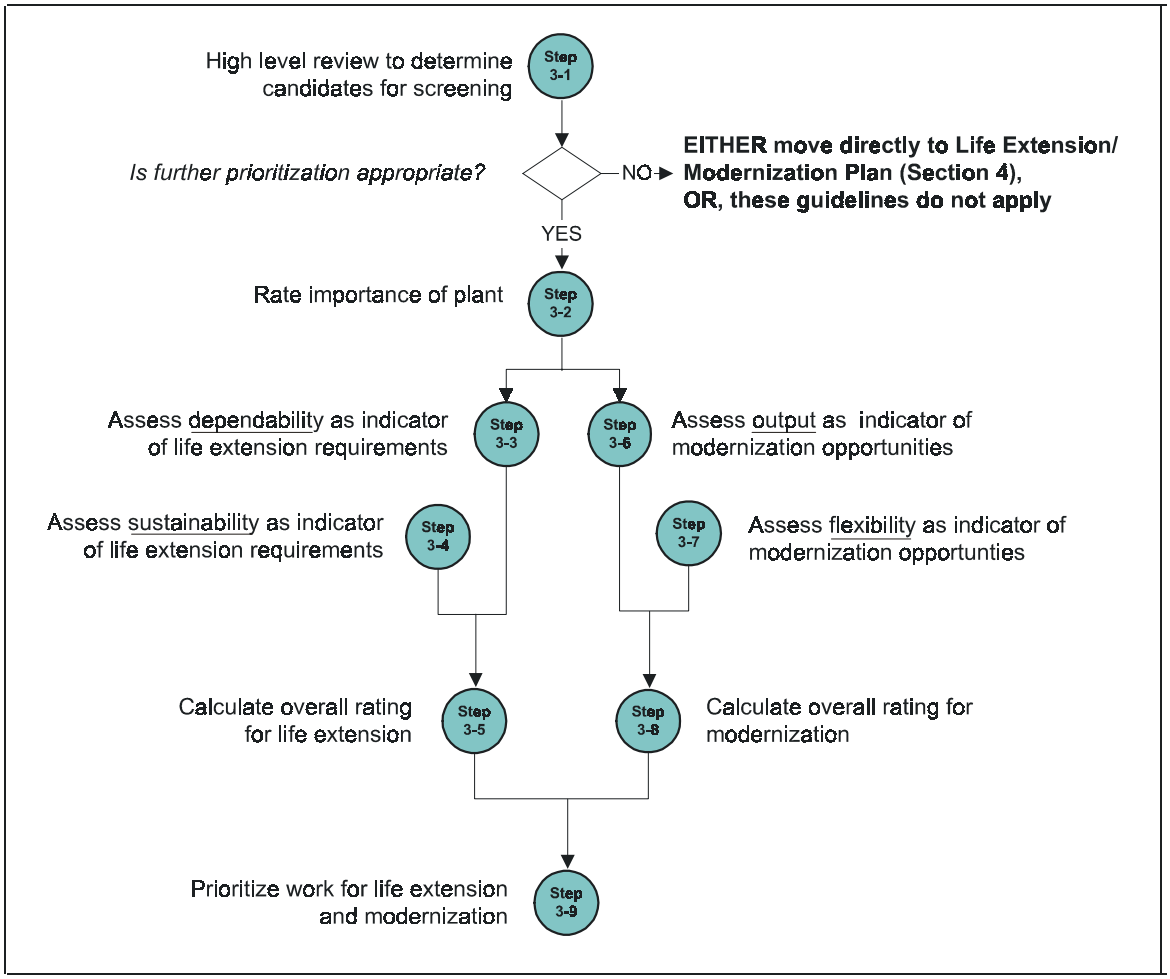

High level review to determine candidates for screening
Step 3-1
Is further prioritization appropriate?
NO
EITHER move directly to Life Extension/ Modernization Plan (Section 4), OR, these guidelines do not apply
YES
Rate importance of plant
Step 3-2
Assess dependability as indicator of life extension requirements
Step 3-3
Step 3-6
Assess output as indicator of modernization opportunities
Assess sustainability as indicator of life extension requirements
Step 3-4
Step 3-7
Assess flexibility as indicator of modernization opportunties
Calculate overall rating for life extension
Step 3-5
Step 3-8
Calculate overall rating for modernization
Prioritize work for life extension and modernization
Step 3-9

Figure 3-1
Screening and Prioritization Process

3.1 Identify Obvious Non-Candidates for Screening

Most hydro plant owners will find that a screening and prioritization process is beneficial as a high level assessment and prioritization tool, particularly if they own a large number of plants. However, in some cases, a preliminary assessment can be used to eliminate this step. This will lead to one of three choices:

- Where it is evident that either a life extension need or modernization opportunity exists, and prioritization is not considered necessary, proceed directly to development of a plan (Section 4).
- Where it is clear that neither a life extension need nor modernization opportunity exists, then no further action is required.
- Where an overall assessment of all plants in the portfolio, or where prioritization is required, then undertake screening and prioritization (Section 3).

Situations where a hydro plant owner could choose to proceed directly to develop a life extension/modernization plan, include:

- Operating performance: Equipment is unavailable for substantial and repeated periods.
- Operating conditions: Present mode of operation is markedly different from original design.
- Non-compliance: There is clear evidence that the plant does not comply with important regulations and action has to be taken.
- High risk: The plant poses a significant risk in terms of impacts on others or commercial losses to owner.
- Fully staffed: The plant has no automation or remote control capability.
- Age: The plant is clearly using significantly outdated equipment.
- Licensing: Licence due for renewal within next 5 years and decision on future known to be critical.

Situations normally suggesting that the plant owner not take the assessment further, include:

- Age: Plant is less than 15 years old.
- History: Full life cycle evaluation completed within last 5 years (if to an appropriate level).
- Institutional and Regulatory: Issues that may render projects unsuitable for life extension and modernization are discussed in Section 6.

Situations that would suggest that the plant owner move into screening and prioritization, include:

- Operating performance: Gradual decline in output, reliability and availability.
- Non-compliance: Suspicion that plant may be non-compliant.
- Risk: Concern that plant may have significant risk exposure.
- Use of water: Significant amounts of water available but not used.

3.2 Rate Importance of Plant

Screening for the importance of the plant is based on the impact of individual plants in the overall portfolio. Ratings for importance are selected from the table of Importance Ratings and recorded on the Step 3-2 Worksheet (located at end of Section 3).

Table 3-1
Step 3-2: Importance Indicators

DESCRIPTOR	INDICATOR
Importance - Importance of each plant in terms of:	**Contribution -** For each plant, the amount (%) of output and revenue compared with the total in portfolio. Also adjust for functionality of the plant and its role in overall profitability of portfolio. Seasonal time of generation also affects contribution.
• contribution to overall portfolio • criticality of units	**Criticality -** For each plant the criticality of losing one unit, based on the financial consequences of a 6 month outage.[1]

Table 3-2
Step 3-2: Importance Ratings

INDICATOR	RATING	DESCRIPTION
Contribution - HAVE[2]	10	High; > 10% of portfolio (in energy production)
	5	Average; ~ 3% of portfolio
	1	Low; < 0.5% of portfolio
Criticality - HAVE[3,4]	10	High; > $1 million
	5	Average; $100,000 to $1 million
	1	Low; < $100,000

Note

1. For the criticality assessment, probabilities of the event are not included. However, consideration of risk cost can be considered during development of life extension and modernization plans.
2. Contribution is rated for present importance of plant, for both life extension and modernization.
3. For this assessment, values of criticality can be considered based on whether the unit is one of many in a plant with minimal spill, or one of a few in a plant with large amount of spill.
4. Other criticality issues include importance to system based on location, and production of ancillary services. Ratings can be adjusted based on judgement.
5. For some plants, depending on their physical parameters, critical features such as penstocks, valves, spillgates, communications and control systems may have extra importance. Again, ratings can be adjusted based on judgement.

3.3 Rate Dependability as Indicator of Life Extension Requirements

"Dependability" as a descriptor is used to assess the performance of a hydro plant and determine what needs to be done over the 20-year life plan. Ratings for indicators of dependability are estimated from the following tables and entered in the Step 3-3 Worksheet (located at end of Section 3). Indicators are for present levels (column headed "HAVE") and the estimate of work required to maintain the present levels over the life cycle (column headed "NEED"). The Life Extension rating for dependability is the product of "Have" and "Need". Note that dependability screening does not indicate if present levels are adequate, only what has been identified as being required to maintain the present level.

Table 3-3
Step 3.3: Dependability Indicators

DESCRIPTOR	INDICATORS
Dependability - Performance of a power plant with regard to • Condition • Performance • Operational risk (safety) • Operational and Maintenance Costs	**Condition** - Qualitative assessment by plant operator, owner, engineers, etc., of the overall condition of key parts of the plant using a high level condition indicator. Includes examining availability of spare parts. Ratings for condition (see following table of Dependability Ratings) are a composite for each unit in a hydro plant. This needs to include all major components of a unit with judgement used to assign a rating value. Guidance for assessing the condition of individual components is given in Technical Volumes 2 to 7. **Performance** - Assessment of the level of service provided and measured by commercial availability. Ratings for performance (see following table of Dependability Ratings) are a composite for each unit. If information is only available for the plant as a whole, this needs to be considered in assigning ratings. Guidance for assessing performance for individual components is given in Technical Volumes 2 to 7. **Operational risk (safety)** - Qualitative assessment of operational risk to equipment, structures and worker safety. Ratings for operational risk (see following table of Dependability Ratings) are a composite for each type of risk. They are assigned only to 1 unit. Typical risks included are potential for loss or damage due to operational activities and worker safety. **Cost** - Annual cost of operation and maintenance (based on condition and performance) are indicators of maintainability. Annual costs for operation and maintenance are given a rating based on a benchmarking against large, medium and small plants. This benchmarking information is shown on figures of Ratings for Operating and Maintenance Costs.

Table 3-4
Step 3-3: Dependability Ratings

INDICATOR	RATING	DESCRIPTION
Condition - HAVE *	0	Excellent
	1	Good (highly likely to last 20 years)
	2	Satisfactory (likely to last 20 years)
	3	Unsatisfactory (some work likely required over 20 years)
	4	Poor (extensive work likely required over 20 years)
	5	Extremely poor (failure expected before 20 years)
Condition - NEED	1	Minor costs
	2	Significant costs
	3	Major costs, equivalent to replacement
Performance - HAVE$^{\Delta}$	0	Excellent
	1	Generally reliable, high availability
	2	Less than 5 forced outages per year (98%+ available)
	3	5 - 10 forced outages per year (90-98% available)
	4	More than 10 forced outages per year (90% available)
	5	Unreliable, availability low
Performance - NEED	1	Minor costs
	2	Significant costs
	3	Major costs, equivalent to replacement
Operational Risk (Safety) - HAVE	0	Excellent
	1	Low risks and/or threat to worker safety
	2	Possible threats to equipment and/or worker safety
	3	Moderate risks to equipment and/or worker safety
	4	High risk to equipment and/or worker safety
	5	Equipment near failure or workplace hazardous
Operational Risk (Safety) - NEED	1	Minor costs to achieve acceptable levels
	2	Significant costs, equivalent to 1 week's output
	3	Major costs, greater than 1 month's output
Operating and Maintenance Costs - HAVE	1-5	See graphs of Ratings for Operating and Maintenance Costs

* "HAVE" ratings indicate the present condition performance and operational risk of the plant and components, with respect to dependability.
"NEED" ratings indicate what needs to be done to provide an acceptable level of dependability over its life for 20 years. These ratings are entered on the Screening Worksheet for Dependability.

Δ For pumped storage and peaking plants, performance may be indicated by Starting Reliability, with similar numerical ratings and descriptors.

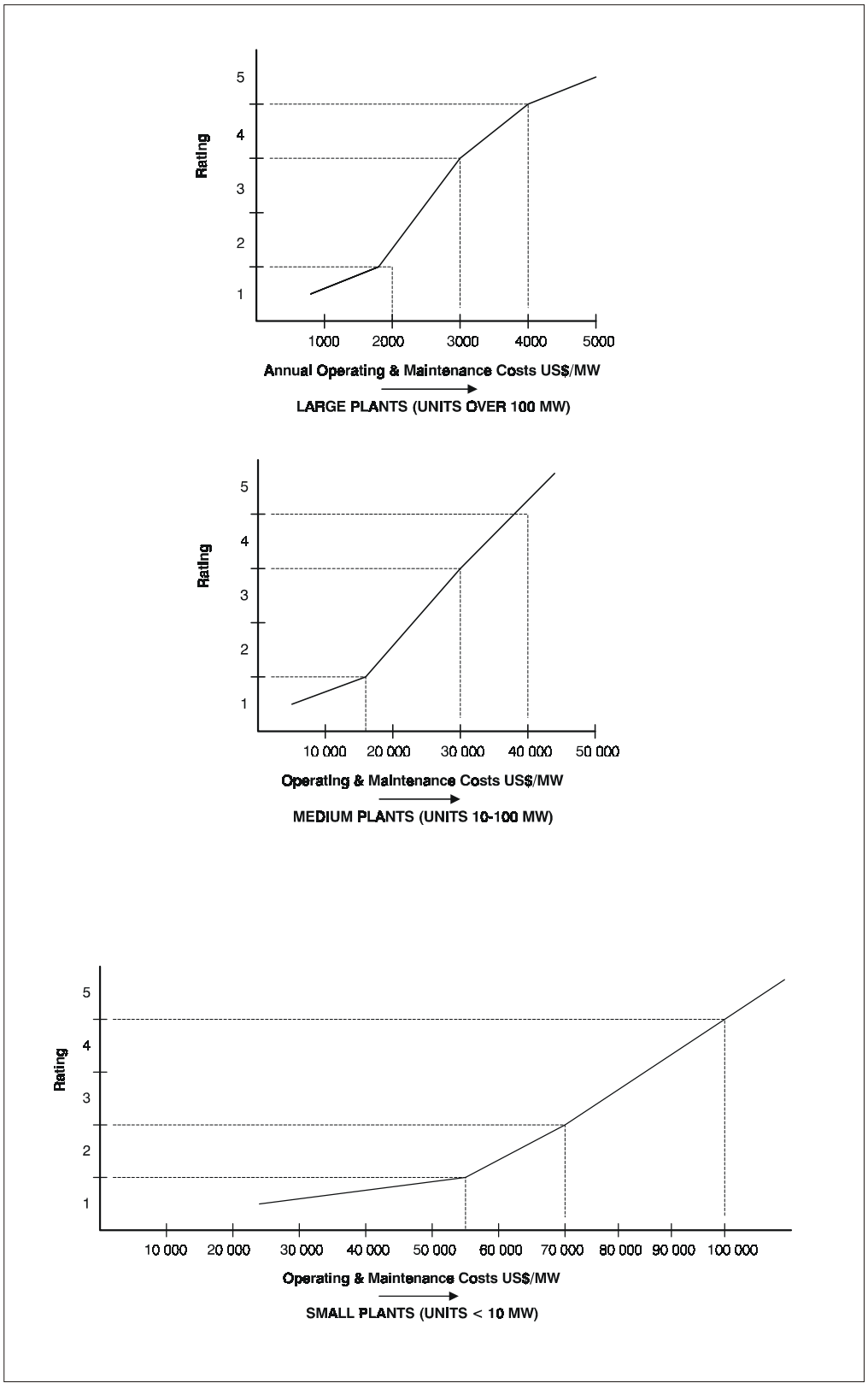


Figure 3-2
Step 3-3: Ratings for Operating and Maintenance Costs

3.4 Rate Sustainability as Indicator of Life Extension Requirements

Screening for the "sustainability" of life extension is based on assessing what needs to be done to provide the same level of sustainability as presently exists. Ratings for sustainability are selected from the table and entered in the Step 3-4 Worksheet (located at end of Section 3), with the present status under "HAVE" and the requirements for life extension under "NEED". The Life Extension rating for sustainability is the product of "Have" and "Need".

If licensing, regulatory compliance, environmental or catastrophic risk issues are identified that would likely prevent further use of the hydro plant, these would be confirmed or resolved before continuing the screening process.

Table 3-5
Step 3-4: Sustainability Indicators

	INDICATORS
Sustainability - Ability of the plant to continue in operation with regard to • Licensing • Regulatory compliance • Environmental issues • Catastrophic risk	**Licensing -** Status of licenses and likelihood of extensions/renewals as relate to modernization potential. Ratings for Licensing have been assessed against the river/ reservoir. The primary rating for licensing is based on whether the project comes under a FERC licence and, if so, the period left in the licence and the expected outcome of either an amendment to an existing licence or a relicensing process. Guidance can be found in Section 6.5. **Compliance** - Applies to regulations relating to use of the water resource, e.g. water use permits, environmental limitations. Ratings for regulatory compliance are project specific and based on any regulations relating to the use of the water resource (other than project licensing). Ratings are assigned only against rivers/reservoir. **Environmental issues** - Activities or events that could jeopardise the continued operation of the plant, e.g. oil spill. Ratings for environmental issues are based on any situation, activity or event that could result in an environmental impact and hence jeopardise continued operation of the plant. **Catastrophic risk** - Qualitative assessment of the potential for catastrophic risk, due to factors such as safety of dams, fire risk, seismic risk or other hazards. Ratings are based on a qualitative assessment of the potential for catastrophic events, their consequences and likelihood. Examples would include, e.g. whether there is a dam safety program in place, and whether there are known deficiencies with regard to standards. The ratings are a composite for risks associated with key components.

Table 3-6
Step 3-4: Sustainability Ratings

NOTE: "HAVE" ratings indicate the present situation relating to licensing, regulatory compliance, environmental and catastrophic risk issues of the plant and components, with respect to sustainability. "NEED" ratings indicate what needs to be done to ensure the plant output can be sustained for 20 years. These ratings are entered on the Screening Worksheet for Sustainability. Supporting information for rating plant sustainability is given under Sustainability Indicators.

INDICATOR	RATING	DESCRIPTION
Licensing* - HAVE	0	No present issues affecting licensing
	1	Minor issues, minimum process
	3	Reasonable process, relicensing likely
	5	Significant process required, relicensing likely
	20	Outcome of relicensing in doubt
	∞	Relicensing not possible
Licensing - NEED	1	Minor activity
	2	Significant time and costs
	5	Extensive time and costs (> 1 month's output)
Regulatory compliance - HAVE	0	No issues affecting compliance
	1	Minor issues
	3	Some issues
	5	Major issues that may affect water use
	20	Hydro plant not in compliance
	∞	Plant will be shut down
Regulatory compliance - NEED	1	Minor activity and cost to achieve compliance
	3	Significant costs or reductions in water
	5	Major cost (>1 month output) or water reduction >10%
Environmental issues - HAVE	0	No issues jeopardising plant operation
	3	Some
	5	Significant issues
	20	Major issues that could close down plant
Environmental issues - NEED	1	Minor activity and cost to mitigate issues
	2	Significant activity and cost
	3	Major activity and cost
Catastrophic risks - HAVE	0	No risks that could affect plant sustainability
	1	Minimal
	3	Some risks to property
	5	Significant risks to property
	20	Extreme risks to property and risk to life
	∞	Unacceptable risks; plant to be closed
Catastrophic risks - NEED	1	Minor activity and cost to mitigate risks
	3	Significant activity and cost
	5	Major activity and cost

* A more complete discussion on Institutional and Regulatory issues, including screening indicators, can be found in Section 6.

3.5 Calculate Overall Rating for Life Extension

The results of the screening for dependability, sustainability and importance are collected to assess requirements for life extension and their relative priorities. The ratings for dependability and sustainability are first compiled on the Step 3-5 Worksheet (located at end of Section 3). The total provides an indication of the overall work required to extend the life of the plant (needs).

A high score for life extension indicates that a plant needs a large amount of activity and hence cost to provide an extension of life. The score does not indicate whether life extension is financially attractive. That is a question that will be addressed in subsequent sections of these guidelines.

A low rating for life extension indicates the plant is generally in good condition with few problems to be addressed.

The results of the screening for importance are used as input if a prioritization of work between plants is sought. It is suggested that the total rating for dependability and sustainability be multiplied by the sum of the rating for importance.

3.6 Rate Output as Indicator of Modernization Opportunities

Screening for modernization identifies opportunities to improve the output over the 20-year life plan at economic cost. Tables provide indicators and ratings for output, for entry on the Step 3-6 Worksheet (located at end of Section 3). Opportunities may include:

- Capacity increases due to increases in water discharge
- Efficiency increases of plant components
- Staffing levels
- Improved equipment and materials

Table 3-7
Step 3-6: Output Indicators

DESCRIPTOR	INDICATORS
Output - How the resources and equipment are used compared with their potential, with regard to use of • Capacity • Efficiency • Staff • Equipment	**Capacity** - Relative to original design and potentially available energy in the river (amount of water spilled, river regulation changes). Reduction may be due to unreliability, undersizing, etc. Rating is based on the ability of the plant to maximize water usage in the river/reservoir. Limitations may be due to reliability, sizing, licences, regulation etc. Information to assist in rating is given in the following tables. **Efficiency -** Efficiency of use through turbines, taking into account all losses. Efficient use of equipment through dispatch, etc. Rating is based on the efficiency of the water passing through the units, i.e. the efficient use of the hydro mechanical equipment in the powerplant. Information to assist in rating is given in the following tables. **Staffing (Human resources) -** Staffing level compared to industry averages for automated and non-automated plants of various ages and types. Rating is based on level of staffing in powerplant relative to industry benchmarking. Information in this area is contained in the following tables. **Equipment -** Age, design and type of principal assets and comparison with new methods, materials criteria, techniques (e.g. potential for runner upgrade based on simple curves). Rating is based on age and type of principal assets and comparison with modern technologies. Information to assist in rating is given in the following tables.

Table 3-8
Step 3-6: Output Ratings

NOTE: "HAVE" ratings indicate the present performance of the component, with respect to output. "CAN" ratings indicate what can be done (i.e. opportunities) to modernize the plant. These ratings are entered on the Screening Worksheet for Output. Supporting information for rating is given under Output Indicators.

INDICATOR	RATING	DESCRIPTION
Capacity - Present use of water resource - HAVE (available energy in river, use of inflows, storage and head)	0 1 3 5	Water spilled infrequently; average head ≈ max head Water spilled annually <5% flow Water spilled frequently 5-10% flow Water spilled near continuously >30% flow; average head <20% max. head
Improved use of water resource (macro) - CAN	1 2 5	Minor, little opportunities, or severe limitations Reasonable Significant
Relative cost to achieve improvements - COST	1 2 3	Major cost, major changes to achieve improvement Average Low costs, easily achieved
Efficiency - Present use of water - HAVE (operation, efficiency, hydraulic losses)	0 1 3 5	Maximum/optimal use Efficient usage Some inefficiencies, minor losses Major inefficiencies, losses
Improved use of water - CAN	1 3 5	Minor, little opportunity or severe limitations Reasonable opportunity Significant improvement opportunities
Relative cost to achieve improved use of water - COST	1 2 3	Major costs Average Low cost
Staff - Present use of human resources - HAVE	0 1 3 5	Plant fully automated, no operating staff Plant automated, some operating staff Plant partly automated Plant manually operated
Improvements to use of human resources - CAN	1 3 5	Minor, little opportunity or severe limitation Reasonable Significant
Relative cost to automate hydro plant - COST	1 2 3	Major costs Average Low cost
Equipment - Present use of equipment - HAVE	0 1 3 5	Equipment new, modern, efficient, reliable Some components modern, others aging Equipment near end of life; performance or design affected Equipment past end of life; performance or design poor
Improved use of equipment - CAN (new materials, more efficient equipment etc.)	1 3 5	Minor opportunities Reasonable Significant
Relative cost for improved equipment - COST	1 2 3	Major costs Average Low cost

Table 3-9
Step 3-6: Modernization Options for Output

SITUATION	POSSIBLE REASONS FOR LIMITATIONS	MODERNIZATION OPTIONS TO INCREASE OUTPUT
Capacity		
Water spilled every year in late spring/early summer	Inadequate regulation/storage of snowmelt	Increase height of dam Uprate units
Occasional and random large spills	Inadequate regulation/storage of intense rain fall	As above
Regular spill	Undersized plant Poor unit availability	Uprate units Improve unit reliability
Efficiency		
Long or rough tunnel/water conduits	Size of tunnel/water conduit causes high friction losses	Enlarge, duplicate line or smooth tunnel/conduit
Plant output and profitability less than optimum	Units running outside optimum ranges or not at optimum times	Change mode of dispatch through new rules or system (program) Provide flexibility from other plants or receive payment
Staffing		
Staff levels above industry average*	Plant not under remote control or automated	Automate
	Collective agreements	Renegotiate
Equipment		
See Table “Life of Hydropower Plant Systems”. Rating is based on present age compared to expected life, with judgement used to account for known condition/performance etc.		

* For large plant with units greater than 100 MW, average O&M staffing for remote controlled plant is about 40 MW/person-year or 7 persons/unit.

For medium plant with units between 10 and 100 MW, average O&M staffing for remotely controlled plant is about 12 MW/person-year or 5 persons/unit.

For small plant with units less than 10 MW, average O&M staffing for remotely controlled plant is about 3 MW/person-year or 2 persons/unit.

Table 3-10
Step 3-6: Life Of Hydropower Plant Systems

PLANT SYSTEMS	EXPECTED LIFE* (Years)	CONSIDERATIONS WHICH AFFECT COMPONENT LIFE
Civil Works		
Dams, canals, tunnels, caverns, reservoirs, surge chambers	60-80	Duration of water rights, quality of work, degree of deterioration, safety, leakage
Penstock and Powerhouse Structures		
Water catchment spillway, sand traps, penstocks, steel linings, roads, bridges	40-50	General condition, design stresses, quality of material, technology level used in design, safety, corrosion, maintenance
Turbines		
Kaplan, Francis	30-40	Safety of operation, leakage, cavitation damage, erosion, corrosion, cracks, decreased efficiency, technology level used in design
Pelton wheel	40-50	
Pump turbine	25-33	
Storage pumps	25-33	
Other Mechanical Installations		
Gates, butterfly valves, special valves, cranes, auxiliary mechanical equipment	25-40	Quality of material, condition, safety of operation, quality of design, design stresses
Electrical Installations		Winding and iron core condition, cleanliness, safety of operation, technology level used in design, general condition, quality of equipment, maintenance
Generator, transformers	25-40	
High-Voltage Switchgear Auxiliary		
Electrical equipment, control equipment	20-25	
Batteries, DC Equipment	10-20	
Energy Transmission Lines		
Steel towers	30-50	Right-of-way, corrosion, safety of operation, climate, quality of material, technology level used in design, capacity
Concrete towers	30-40	
Wooden poles	20-25	
Cables	25-40	

* Economic life based on a 1975 study of SEV/Swiss Electrotechnical Association, and updated by more recent experience.

3.7 Rate Flexibility as Indicator of Modernization Opportunities

Screening considers opportunities to improve the level of plant flexibility over the 20-year life of the project at economic cost. (See Section 1.3.) Step 3-7 gives indicators for plant flexibility and ratings for entry on the Step 3-7 Worksheet (located at end of Section 3). Opportunities may include:

- Range of products: Additional ancillary services
- System requirements: System stability and voltage control
- Services: Water resources

Table 3-11
Step 3-7: Flexibility Indicators

DESCRIPTORS	INDICATORS
Flexibility - Range of products of power plant and their versatility.	**Products, ancillary services** - Having value greater than the cost of production. Ratings for the range of products from a hydro plant are based on: Capability to deliver Base Load Capability to operate Load Factoring (daily stop start) Capability to operate as Swing Bus (frequent daily load changes) Automatic Generation Control operation (AGC) **System stability -** Meeting requirements for system stability. Ratings for system support are based on meeting system requirements through: Voltage Support through VAR control Black Start capability Local Load, islanded operation capability **Services** - Other services that hydro plants can provide through water resources Ratings for services from a hydro plant are based on: River regulation for other hydro plants Reservoir Storage Domestic Water supply Irrigation supply Recreational Environmental General benefits at other plants

Table 3-12
Step 3-7: Flexibility Ratings

NOTE: "HAVE" ratings indicate the present range of products/services, with respect to flexibility. "CAN" ratings indicate what can be done (i.e. opportunities) to modernize the plant. These ratings are entered on the Screening Worksheet for Flexibility.

INDICATOR	RATING	DESCRIPTION
Present Range of Products - HAVE	0	Large range, modern equipment, good capability and/or optimal usage
	3	Average range
	5	Low range, limitation with water, equipment and or operation
Opportunities to improve Range of Products - CAN	1	Minor opportunities/high limitations
	3	Reasonable
	5	Significant - improvements to equipment, capability and/or usage
Relative cost to improve Range of Products - COST	1	Major costs, equipment and outage
	2	Significant cost equipment or outage
	3	Low cost
Present System Support - HAVE	0	High level of support
	3	Average
	5	Low
Opportunities to improve System Support - CAN	1	Minor opportunities for improvement
	2	Reasonable
	3	Significant
Relative cost to improve System Support - COST	1	Major costs
	2	Significant
	3	Low cost
Present Services - HAVE	0	High level of services
	1	Average
	2	Low
Opportunities to improve Services - CAN	1	Minor opportunities for improvement
	2	Reasonable
	3	Significant
Relative cost to improve Services - COST	1	Major costs
	2	Significant
	3	Low costs

3.8 Calculate Overall Rating for Modernization

The results of the screening for output and flexibility are collected to assess opportunities for modernization and their relative priorities. The Step 3-8 Worksheet collects the ratings for the indicators related to modernization. The total provides an indication of the overall attractiveness of undertaking the work required to modernize the plant (opportunities).

A high score for modernization indicates that there are ample opportunities to improve the performance of the plant. This does not necessarily mean that modernization is economic or technically feasible. There are questions that will be addressed in subsequent sections of these guidelines.

A low rating for modernization indicates few opportunities.

The results of the screening for importance are used as input if a prioritization of work between plants is sought. It is suggested that the total rating for output and flexibility be multiplied by the rating for importance.

Table 3-13
Step 3-2 Worksheet: Plant Importance

COMPONENT	CONTRIBUTION (HAVE)		CRITICALITY (HAVE)		TOTAL
Powerplant No. 1		+		=	
Powerplant No. 2		+		=	
Powerplant No. 3		+		=	
Powerplant No. 4		+		=	

Ratings for each plant are entered into the Summary Ratings for Life Extension.

Table 3-14
Step 3-3 Worksheet: Dependability

	CONDITION			PERFORMANCE			OPERATION RISK (SAFETY)			O&M COST
COMPONENT	**HAVE**	**NEED**	**LIFE EXT**	**HAVE**	**NEED**	**LIFE EXT**	**HAVE**	**NEED**	**LIFE EXT**	**HAVE**
Powerplant No. 1		x	=		x	=		x	=	
Powerplant No. 2		x	=		x	=		x	=	
Powerplant No. 3		x	=		x	=		x	=	
Powerplant No. 4		x	=		x	=		x	=	

Notes: HAVE: Present situation (What we "have" at present.)
NEED: Requirement for life extension (What "needs" to be done.)
LIFE EXT: Life extension rating for specific indicator, calculated as the product of "HAVE" and "NEED".

Ratings for each plant are entered into the Overall Ratings for Life Extension (Step 3-5 Worksheet).

Table 3-15
Step 3-4 Worksheet: Sustainability

	LICENSING			REGULATORY COMPLIANCE			ENVIRONMENT			CATASTROPHIC RISK		
COMPONENT	**HAVE**	**NEED**	**LIFE EXT**	**HAVE**	**NEED**	**LIFE EXT**	**HAVE**	**NEED**	**LIFE EXT**	**HAVE**	**NEED**	**LIFE EXT**
Powerplant No. 1	x	=		x	=		x	=		x	=	
Powerplant No. 2	x	=		x	=		x	=		x	=	
Powerplant No. 3	x	=		x	=		x	=		x	=	
Powerplant No. 4	x	=		x	=		x	=		x	=	

Notes: HAVE: Present situation (What we "have" at present.)
NEED: Requirement for life extension (What "needs" to be done.)
LIFE EXT: Life extension rating for specific indicator, calculated as the product of "HAVE" and "NEED".

Ratings for each plant are entered into the Overall Ratings for Life Extension (Step 3-5 Worksheet).

Table 3-16
Step 3-5 Worksheet: Overall Ratings for Life Extension (For Each Plant)

INDICATOR	PLANT SCORE*	COMMENTS
DEPENDABILITY		
Condition		
Performance		
Safety		
Cost		
SUSTAINABILITY		
Licensing		
Compliance		
Environmental		
Catastrophic Risk		
TOTAL		
IMPORTANCE		
Contribution		
Criticality		

* For each indicator, this is the sum of the "LIFE EXT" column on the screening worksheets for dependability and sustainability.

Table 3-17
Step 3-6 Worksheet: Output

	CAPACITY (WATER RESOURCE)				EFFICIENCY (WATER USE)				STAFF				EQUIPMENT			
COMPONENT	HAVE	CAN	COST	MODERN	HAVE	CAN	COST	MODERN	HAVE	CAN	COST	MODERN	HAVE	CAN	COST	MODERN
Powerhouse No. 1		x	x	=		x	x	=		x	x	=		x	x	=
Powerhouse No. 2		x	x	=		x	x	=		x	x	=		x	x	=
Powerhouse No. 3		x	x	=		x	x	=		x	x	=		x	x	=
Powerhouse No. 4		x	x	=		x	x	=		x	x	=		x	x	=

Notes: HAVE: Present situation (What we "have" at present.)
CAN: Opportunities for modernization (What "can" be done to improve the output.)
COST: Relative cost to increase output.

MODERN: Modernization rating for the component, calculated as the product of "HAVE", "CAN", and "COST".

Ratings for each plant are entered into the Overall Ratings for Modernization (Step 3-8 Worksheet).

Table 3-18
Step 3-7 Worksheet: Flexibility

	PRODUCTS				SYSTEM SUPPORT				SERVICES			
COMPONENT	**HAVE**	**CAN**	**COST**	**MODERN**	**HAVE**	**CAN**	**COST**	**MODERN**	**HAVE**	**CAN**	**COST**	**MODERN**
Powerhouse No. 1		x	x	=		x	x	=		x	x	=
Powerhouse No. 2		x	x	=		x	x	=		x	x	=
Powerhouse No. 3		x	x	=		x	x	=		x	x	=
Powerhouse No. 4		x	x	=		x	x	=		x	x	=

Notes: HAVE: Present situation (What we "have" at present.)
CAN: Opportunities for modernization (What "can" be done to improve the flexibility.)
COST: Relative cost to increase flexibility.

MODERN: Modernization rating for the component, calculated as the product of "HAVE", "CAN", and "COST".

Ratings for each plant are entered into the Overall Ratings for Modernization (Step 3-8 Worksheet).

Table 3-19
Step 3-8 Worksheet: Overall Ratings for Modernization (For Each Plant)

INDICATOR	PLANT SCORE*	COMMENTS
OUTPUT		
Capacity		
Efficiency		
Staff		
Equipment		
FLEXIBILITY		
Products		
System Support		
Services		
TOTAL		
IMPORTANCE		
Contribution and Criticality		

* For each indicator, this is the sum of the Modernization columns on the screening worksheets for output and flexibility.

3.9 Prioritize Work for Life Extension or Modernization

The results of the overall ratings for life extension (Step 3-5) and for modernization (Step 3-8) are collected for each plant. The results are then assessed as to whether either life extension or modernization appears worthwhile.

Using the importance ranking, the results for each plant can be listed and prioritized. This can assist in selecting those plants which have the greatest needs, opportunities and the highest impact for the hydro plant owner.

A final step is to collect all the needs and opportunities identified in this screening and prioritization process for consideration in future stages of development.

4
LIFE EXTENSION AND MODERNIZATION PLAN

The concepts of life cycle management, life extension and modernization of hydroelectric plants have been introduced in Section 1.3. This section outlines a process to develop a Life Extension and Modernization Plan (the Plan) for those plants identified by Screening and Prioritization (Section 3) to justify a more detailed assessment. This will:

- Optimize the life cycle of plant assets and plan for their timely refurbishment or replacement (life extension).
- Identify methods to improve the financial prognosis of those plants rated as having the most potential to improve (modernization).
- Provide improved cash flow forecasts.

The Plan provides:

- Assessment of plant (equipment and structures) condition.
- Review of present cost and level of service.
- Life extension spending plan to maintain present performance and condition.
- Details of existing management strategies and recommendations for improvement.
- Long-term spending and revenue plan, incorporating modernization options.
- Financial forecast and cash flow based on the life extension and/or modernization plans.

The Plan has three stages:

- Survey the plant to identify Needs and Opportunities, Steps 4-1 to 4-5.
- Screen the Needs and Opportunities to ensure they meet Plant Strategies, and propose appropriate activities, Steps 4-6 and 4-7.
- Model the proposed activities to determine their effect on the business, Steps 4-8 to 4-10.

Step 4-11 is the feedback loop to update the Plan periodically for continual improvement to the business.

The Life Extension and Modernization Plan process is shown on Figure 4-1.

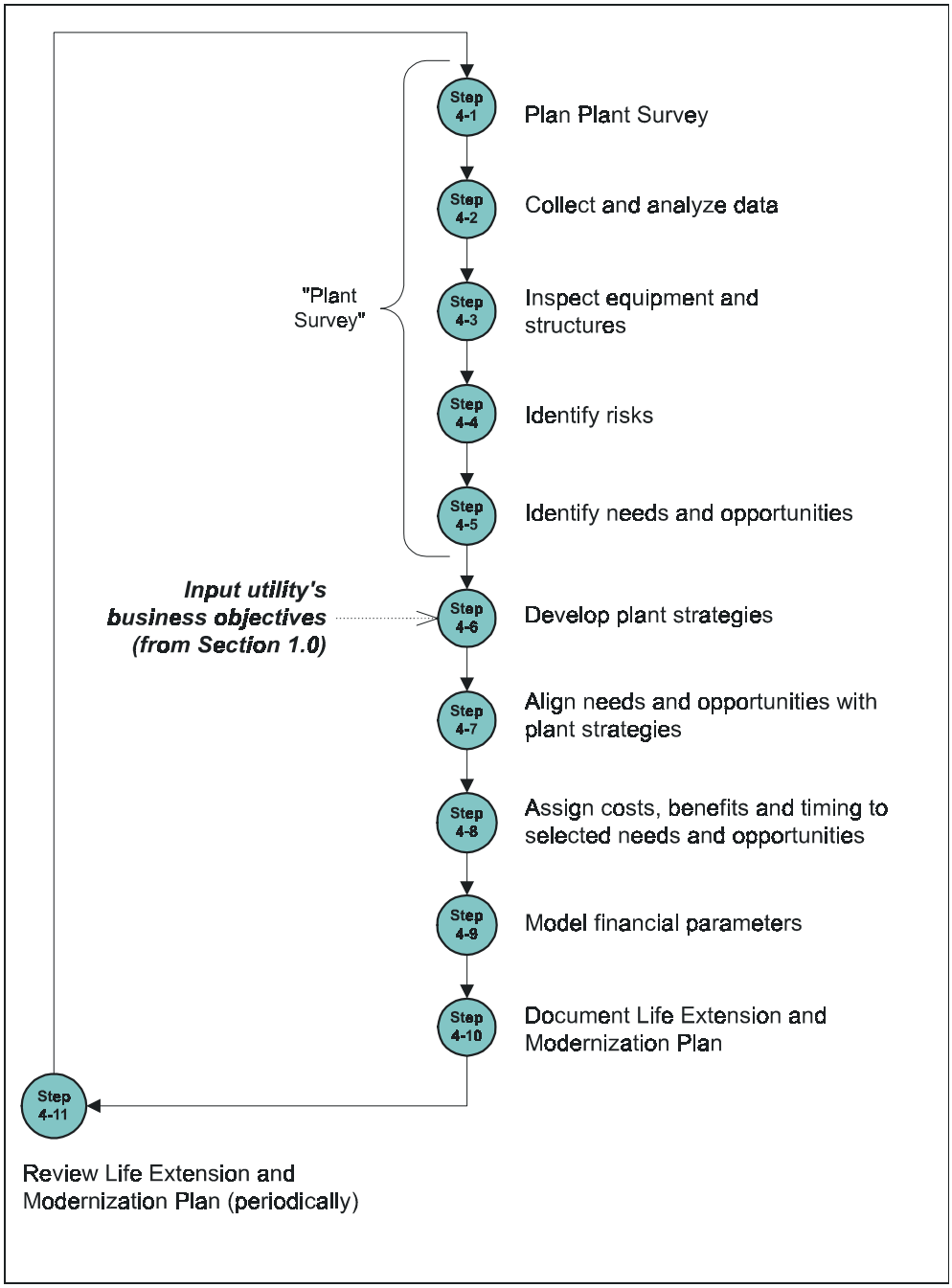


Figure 4-1
Life Extension and Modernization Plan

4.1 Plan Plant Survey

The Plant Survey is a target oriented and systematic analysis of the hydro plant with the prime objective of identifying:

- life extension needs, based on maintaining, or restoring, the plant to its expected condition, risk exposure and performance.
- modernization opportunities, based on improving the output and the financial performance of the plant.

Data and information is gathered in Steps 4-2 and 4-3 and risks identified in Step 4-4. Step 4-5 collates the information and produces a Needs and Opportunities Table. This process is shown in Table 4-1.

Table 4-1
Plant Survey Methodology for Assessing Needs and Opportunities

INFORMATION SOURCES		
INSPECTION AND TESTS	DATA AND INFORMATION	IDENTIFICATION OF RISK
• Operating logs • Walk around (overview inspection) of equipment • Interview with site personnel for operating and maintenance history and to complete generic equipment information sheets • Review of test results	• Repair; frequency, duration, cost • Outage; frequency, type, cause and impact • Spare Parts; availability • Usage of plant • Maintenance reports • Original plant design reports • Drawings	• Reservoir/dams • Water conveyances • Hydro plant structure • Hydro plant equipment

Needs and Opportunities Table	
Description	Major repair history
Condition	Reliability history
Remaining service Life	Upgrade/mod. Opportunities
Maintenance requirements	Spare parts inventory

Organization of the Work

The process described in this section is at the overview level.

The plant survey process uses an appropriate level of effort to identify the general needs of the plant and opportunities for modernization. The assessing engineers who undertake this work are generalists with a broad level of knowledge covering all aspects of the plant. At this level of effort and with generalist staff, the accuracy of the information will be limited and the survey will only provide “best estimate” predictions of activities for the next 20 years.

If the work is undertaken at one time for a number of hydro plants, there will be economies of scale which reduce the unit cost of each plant survey. There will also be an improved consistency of results due to assessment of the respective components of several plants by the same people.

Similarly, experience has shown the benefits of using a team approach. The core of each is three engineers - electrical, mechanical and civil, experienced professionals who are prepared to exercise judgement and make subjective statements. This assessment team functions most effectively when supported by a Project Manager, researchers such as interns or co-op students and a word processor. The support team researches, retrieves, compiles and summarizes all information and records on the plant, following rules to keep the volume manageable yet pertinent. Once the data is compiled, the assessment team analyses it and carries out a site inspection, followed by the analysis of needs and opportunities.

4.2 Collect and Analyze Data

Data collection provides the main indicator of the health of plants and assets. It is best gathered prior to the visit to the site, built on during the visit and completed thereafter. From the analysis of plant historical data, life extension needs become apparent and modernization opportunities can often be identified.

As a first step in data collection it is helpful to categorize the equipment:

- critical equipment (high risk)
- problem equipment (chronic)

The most important, critical equipment, includes items which, on failure, could result in complete or significant loss of generation, lengthy outages and expensive repair or replacement costs. Equipment and components particularly susceptible to time-dependent failure mechanisms are included. Also, equipment whose failure could result in danger to the plant or its personnel.

Problem equipment includes all items which have been identified on the basis of maintenance records at the plant or at other plants with similar equipment.

Both in the selection of equipment and components for each category and in the subsequent data collection and analysis the focus is on the impact of the aging mechanisms.

Sources for data collection include:

- original design documentation
- manufacturer’s manuals and drawings
- commissioning and maintenance test and inspection records
- operating and maintenance logs
- interviews with operating and maintenance staff
- where applicable, visual inspection of the equipment

Asset Register

For consistency, a single standard hierarchical registry system, the "Asset Register" is used for all equipment (this covers all assets from reservoir to tailrace and from turbine to transformer). A generic Asset Register is provided in Table 4-2. To help with preparation of the Asset Register, a set of 10 to 20 drawings is collected. These provide high level component and nameplate information and becomes the project set for data gathering and reference during report preparation.

In conjunction with the Asset Register it is important to use a computerized data base for the orderly logging of the equipment data. This leads naturally to data storage, data analysis and condition assessment activities. The data base may also be used for preventive or predictive maintenance planning and spare parts inventories.

Also important is the collection of reports on assessment, studies, tests and previous projects. This is best indexed by activity and referenced to the data base.

Operational and Cost Data

In general, there is large amount of stored data at most plants, often held in different unconnected files, libraries or databases. The team gathering and assessing data, needs to understand and be familiar with all information storage methods.

The process includes an initial review of the drawings set to establish an equipment list and categories, and a review of documentation for the purpose of assessing plant condition history and degree of obsolescence. This review often indicates if the equipment is performing up to its original design capability and rating. For civil components the review can also include original design records which indicate whether the present/original design is acceptable by modern standards. Previous investigations of improvements and details of those installed, are also collected (for modernization information).

Maximum benefit is achieved if the information is collected, processed and analyzed prior to visiting the site (Step 4-3). This provides the interviewers with trends and anomalies on which they can form their questions. It is also beneficial that the data collected be in a form that is consistent from site to site, to allow comparisons and checks (benchmarking) between sites.

While most utilities have been compiling data on their plant for years, the accuracy (e.g. allocation of maintenance costs to individual plant) may, in places, be poor. If the information is not accurate or if it is misallocated, this will soon become apparent during the site visit. It is beneficial to discuss the issue of accuracy with the data providers. This could:

- improve the reporting especially if the potential for better decisions is accepted.
- allow an estimate of necessary adjustment to compensate for the inaccuracies.

Optimally, five to ten years of operational and cost data is collected, compiled and entered in the Data Analysis Tables (See under Documentation, later in Step 4-2).

It is suggested that the format for collecting this data uses the five Performance Indicators described in Section 2.3.1. This data, as noted in the following five boxes (one for each Performance Indicator) can provide valuable and necessary information.

Dependability

- The number of outages
- The cause of each outage, classified as:
  - foreign interference - e.g. blockage of the trashracks
  - adverse environment - usually outages caused by weather conditions
  - equipment failure
  - human element - mis-operation
  - system condition - e.g. line failure
  - unknown
- The equipment/structure to which the outage was assigned.
- The consequences of the outages.

A review of the data on forced outages can provide valuable insight into causes.

- % time operating; for each unit.
- % time of year synchronous condensing, for each unit.
- % time off-line but available: i.e. units are available but not on-line due to lack of water, other plants have been dispatched, or power not required.
- % time the off-line in maintenance, either planned or forced (unplanned), i.e. time units could be running as water is available and energy is required.
- Maintenance cost data for each major piece of equipment including materials and labour. These provide a general indication of equipment condition.
- Capital project reports. These provide general information on asset replacement or rehabilitation.

The review of maintenance records will indicate how extensively the equipment has been maintained. The review will also identify problem areas if repairs are frequent and/or repetitive.

Sustainability

- licence information
- environmental issues
- risk issues i.e. dam safety, seismic, fire protection, oil spill containment, security

Output

- inflow cubic ft/sec (m^3/s)
- spill cubic ft/sec (m^3/s)
- turbine discharge cubic ft/sec (m^3/s)
- statutory release cubic ft/sec (m^3/s)
- outflow data cubic ft/sec (m^3/s)

A review of available water used for operation can identify opportunities for increased water utilization.

- monthly generation (MWh), both heavy and light load hours.
- the available generation if all inflow, less required statutory releases, could be used, and
- the maximum possible generation based on plant capacity if unlimited water was available.

A review of generation information can identify utilization factor, major product revenue and machine usage, and hence opportunities for improvement.

- Storage changes cubic ft/sec. days (m^3/s days).
- % use of the storage capacity of the reservoir.
- Use of reservoir to maximize heavy load hour operation (when the value of energy is high) in order to maximize plant revenues.

A review of reservoir operation information can identify whether the water resource is being effectively utilized.

- Staff versus contract labour statistics ($/year). Optimization of annual labour costs involves getting the right mix of contract and staff labour.
- Skill sets required for specific plant positions. Opportunities for multi-tasking can be identified from this data.
- Union work site regulations/staffing.

Background on Output can be found in Appendix B.

Flexibility

- Energy
- Portfolio Services
- Storage and River System Regulation
- Ancillary Transmission Services
- Flexible Operation
- External Services

Background on Flexibility can be found in Appendix B.

Profitability

- Forecast of value of products over life cycle (20 years) broken down into units compatible with the utility financial group and allocated accordingly
- Ongoing expenditures for operation and maintenance and for plant capital projects
- Predicted product quantities
- Allocated fixed costs (finance, overhead, etc.)

Condition Assessment

The assessment of the condition of equipment starts during data collection. It is a systematic analysis of the critical components to:

- estimate the remaining life.
- recommend suitable actions to reduce technical and economic risks during continued operation.

Estimating remaining life of critical plant components uses information from operational history, maintenance records, design of the equipment, as well as experience from other plants with similar equipment. It is the period during which the component continues to provide the required level of service and cost of service. This is usually limited by:

- the occurrence of critical cracks.
- erosion, wear, corrosion and damage.
- low output compared to the latest designs.
- excessive frequency of inspections, maintenance and repairs.

The assessing engineer uses Volumes 2 to 7 of the Technical Guidelines to assess the information from **both** the desktop studies and the site inspection.

Documentation

The operational and cost data gathered by the assessing engineers are collected in Tables 4-3 and 4-4.

Table 4-3, Data Analysis Table is for the overall hydro plant.

It includes a list of general issues and the performance indicators to use for the overall hydro plant assessment. Most of the data used to complete the table is obtained from existing desktop studies.

Table 4-4, Data Analysis and Inspection Results[11] is for specific equipment.

It includes a generic asset register of typical plant equipment and structures and the performance indicators used to assess their condition and identify needs and opportunities. Data used to complete the table is obtained from both desktop studies and the inspection of the equipment and structures (Step 4-3).

In each of Volumes 2 to 7 of the Technical Guidelines, there will be Tables similar to Table 4-4 covering specific equipment. On this basis, the Technical Guidelines will provide basic data and information to help identify needs and opportunities for each plant component and then to integrate these for the entire plant. Volumes 2 to 7 will also provide information to estimate costs of activities, usually based on standard cost curves and tables. The complete set of Tables 4-4 for an entire plant can be built in this manner.

[11] Table 4-4 given in this section is a sample only. The full set of Tables for equipment and structures will be developed and contained in Volumes 2, 6 and 7 of these Guides.

Table 4-2
Asset Register

- 1.0 GENERATING UNITS
  - 1.1 Unit 1
    - 1.1.1 Turbine
      - 1.1.1.1 General
      - 1.1.1.2 Runner
      - 1.1.1.3 Wicket Gates/Needle Valve and Operating Assembly
      - 1.1.1.4 Turbine Bearings and Lubrication
      - 1.1.1.5 Deflectors
    - 1.1.2 Governor
      - 1.1.2.1 Hydraulic System
      - 1.1.2.2 Governor Controls
    - 1.1.3 Turbine Inlet Valve
      - 1.1.3.1 Valve
      - 1.1.3.2 Actuator
    - 1.1.4 Generator
      - 1.1.4.1 Stator
      - 1.1.4.2 Rotor
      - 1.1.4.3 Generator Bearings and Lubrication
      - 1.1.4.4 Braking System
      - 1.1.4.5 Stator Coolers
      - 1.1.4.6 Generator Fire Protection
    - 1.1.5 Excitation System
      - 1.1.5.1 Exciter and Brushgear
      - 1.1.5.2 Automatic Voltage Regulator
      - 1.1.5.3 Field CB and Discharge Resistor
    - 1.1.6 Unit Protection and Control
      - 1.1.6.1 Unit Protection
      - 1.1.6.2 Unit Control
      - 1.1.6.3 Alarm Indication and Monitoring
      - 1.1.6.4 Synchronizing System
    - 1.1.7 Unit Circuit Breaker
    - 1.1.8 Generator LV Leads and Terminal Equipment
    - 1.1.9 Unit Transformers
    - 1.1.10 Unit Cooling Water
  - 1.2 Unit 2
  - 1.3 Unit 3, etc.
- 2.0 POWERHOUSE
  - 2.1 Powerhouse Auxiliary Equipment and Systems
    - 2.1.1 Station Service AC
      - 2.1.1.1 Circuit Breakers
      - 2.1.1.2 Transformers
      - 2.1.1.3 Standby Power Supply
      - 2.1.1.4 Protection and Control
    - 2.1.2 Station Service DC
      - 2.1.2.1 Battery System
      - 2.1.2.2 Protection and Control
    - 2.1.3 Cable Support Systems
    - 2.1.4 Grounding Systems
    - 2.1.5 Lighting Systems
    - 2.1.6 Compressed Air Systems
      - 2.1.6.1 Station Service Air
      - 2.1.6.2 Governor Air
    - 2.1.7 Water Systems
      - 2.1.7.1 Raw Water
      - 2.1.7.2 Domestic Water
    - 2.1.8 Drainage Systems
      - 2.1.8.1 Unwatering System
      - 2.1.8.2 Station Drainage System
      - 2.1.8.3 Sewage Treatment
    - 2.1.9 Fire Protection System
    - 2.1.10 HVAC Systems
  - 2.2 Cranes
    - 2.2.1 Powerhouse Crane
    - 2.2.2 Tailrace Gantry Crane
  - 2.3 Draft Tube Gates
    - 2.3.1 Gates
    - 2.3.2. Stoplogs
    - 2.3.3 Hoist
  - 2.4 Civil Works
    - 2.4.1 Powerhouse Structure
    - 2.4.2 Draft Tube
    - 2.4.3 Tailrace
    - 2.4.4 Powerhouse Roof
    - 2.4.5 Miscellaneous Buildings
    - 2.4.6 Powerhouse Access
- 3.0 SWITCHYARD
  - 3.1 Switchgear
    - 3.1.1 Circuit Breakers
    - 3.1.2 Disconnect Switches
    - 3.1.3 P&C Switchboard
      - 3.1.3.1 Line Protection
      - 3.1.3.2 Switchyard Equipment
      - 3.1.3.3 Indication and Metering
      - 3.1.3.4 Alarms and Monitors
      - 3.1.3.5 Panels and Cabling
  - 3.2 Reactive Equipment
    - 3.2.1 System Transformers
    - 3.2.2 Reactors
    - 3.2.3 CT's and CVT's
  - 3.3 Buswork
  - 3.4 Lightning Arrestors
  - 3.5 Cables
  - 3.6 Grounding Systems
  - 3.7 Civil Works
  - 3.8 Distribution Feeders
  - 3.9 Station Service
    - 3.9.1 DC
    - 3.9.2 AC
- 4.0 DAM, FOREBAY AND RESERVOIR
  - 4.1 Dam
    - 4.1.1 Dam Structure
      - 4.1.1.1 Right Abutment
      - 4.1.1.2 Left Abutment
    - 4.1.2 Dam Drainage and Instrumentation
    - 4.1.3 Reservoir Slopes and Shoreline
    - 4.1.4 Debris Boom
    - 4.1.5 Access Roads
- 5.0 SPILLWAY, INTAKES AND OUTLET WORKS
  - 5.1 Spillway
    - 5.1.1 Spillway
      - 5.1.1.1 Spillway Structure
      - 5.1.1.2 Spillway Gates, Hoists,Controls and Flashboards
      - 5.1.1.3 Spillway Stoplogs and Hoist
      - 5.1.1.4 Spillway Bubbler System
      - 5.1.1.5 Spillway Normal and Standby Power
  - 5.2 Intakes
    - 5.2.1 Intake Structure
    - 5.2.2 Trashracks
    - 5.2.3 Intake Gates and Hoists
      - 5.2.3.1 Intake Gates
      - 5.2.3.2 Intake Gate Hoists
      - 5.2.3.3 Protection and Control
    - 5.2.4 Intake Stoplogs
    - 5.2.5 Intake Bubbler System
- 6.0 CONDUITS
  - 6.1 Penstocks
    - 6.1.1 Pipe
    - 6.1.2 Supports and Anchors
    - 6.1.3 Housing
  - 6.2 Tunnels
  - 6.3 Penstock Inlet Valves
    - 6.3.1 Valve
    - 6.3.2 Actuator
  - 6.4 Pipelines'
  - 6.5 Surge Towers/Pressure Relief Mechanism
  - 6.6 Canal and Headworks
- 7.0 CONTROL ROOM EQUIPMENT
  - 7.1 Protection and Control
  - 7.2 Alarms Indication and Monitoring
  - 7.3 Communications
    - 7.3.1 SCADA
- 8.0 MISC. BUILDINGS
- 9.0 DIVERSIONS
  - 9.1 #1 Diversion
    - 9.1.1 Dam
    - 9.1.2 Spillway
    - 9.1.3 Miscellaneous

Table 4-3
Step 4-2: Data Analysis Table for Hydro Plant

This table is used to collect information for identifying life needs and opportunities based on plant performance data.							
Performance Indicator	**Descriptor or Issue**	**Performance Information**	**Results of Assessment**	**Possible Life Extension Needs**	**Activities/Projects to meet needs (including timing and cost)**	**Possible Modernization Opportunities**	**Activities to Achieve Opportunities (including timing and cost)**
Dependability	• Reliability • Availability • Maintainability • Safety & operational risks	• Outages/yr; SDR's/yr* • Causes of outages • % time in planned, maintenance & forced outage/yr • Annual maintenance budget/hrs operation/MW • Annual safety reports • Plant risk rating		• Condition Monitoring Program • Upgrade transmission lines protection • Increase preventive maintenance budget			
Sustainability	• Licensing • Regulatory compliance • Environmental compliance • Catastrophic risk	• Water license issues • $ cost of fines on annual basis. • Warnings from agencies on non-compliance • Dam Safety reports. • Plant risk rating • FERC licensing		• Upgrade plant fire system and oil spill containment • Seismic upgrading • Upgrade dam safety monitoring equipment			

* System Disturbance Reports

Table 4-3
Step 4-2: Data Analysis Table For Hydro Plant (continued)

This table is used to collect information for identifying life needs and opportunities based on plant performance data.							
Performance Indicator	**Descriptor or Issue**	**Performance Information**	**Results of Assessment**	**Possible Life Extension Needs**	**Activities/Projects to meet needs (including timing and cost)**	**Possible Modernization Opportunities**	**Activities to Achieve Opportunities (including timing and cost)**
Output	• Water utilization • Generation • Reservoir operation • Workforce costs	• % spill (spill/inflow); Max. avail. Generation from water (power studies) • Monthly generator data • Use of storage to maximize high load hour operation; % use of available storage • Contract vs staff labour costs & hours				• Capacity increases • Efficiency upgrades • Reservoir optimization • Plant automation	
Flexibility	• Product mix	• Energy • Capacity • Storage and river system regulation • Ancillary transmission services • Flexible operation • External services				• Improve product flexibility and product mix	
Profitability	• Return on assets • NPV	• Life cycle costs • Value of plant					

Table 4-4
Step 4-2: Sample Only – Data Analysis and Inspection Results Table for Equipment and Structures

Asset No.	Equipment or Structure (Asset name and description)	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.1	Turbine • Age • Type (Francis, Kaplan, etc.) • Ratings: speed; head; efficiency; design & max. MW; discharge	• Vibration Levels • Rough zones • Annual outage time • Maximum output vs rating • Annual maintenance/ service ($/yr) • Coating condition • Seals condition (if applicable) • Structural integrity	• Remaining service life • Regular maintenance activities • Spare parts availability • Rehability history • Major repair history	• Repainting • Seal water improvements to lengthen life of seals • Welding	• See look-up tables for predicting expenditures	• Vibration monitoring system • Control scheme to avoid rough zones • Reduce seal leakage with improved design • Tripod removal to increase unit efficiency • Air injection, possibly via an intelligent controller or simpler on/off blower, to increase unit efficiency • Investigate whether plant head conditions match turbine rating	
1.1.1.1	Runner • Type • Age • Diameter	• Level of cavitation • Annual welding ($/yr) • Structural integrity		• Cavitation and erosion repair (welding) • Recoating to prevent cavitation • Replace due to end of service life		• Replace with new redesigned runner to increase unit efficiency	

4.3 Inspect Equipment and Structures

Inspections at the site normally take 1 to 2 days, depending on the size and complexity of the plant. To maximize the benefit, it is essential that senior plant staff and knowledgeable trades are available.

The main functions of the site inspection are to:

- Confirm or update the Asset Register (Table 4-2).
- Obtain or confirm nameplate information and expand upon asset descriptions.
- Confirm operations information including dispatch strategies, cost and operation constraints, spillage, outages and high maintenance cost items.
- Interview site personnel on maintenance issues and condition of equipment and structures.
- "Walk around" the site (overview inspection) to confirm general condition of all equipment.
- Review operating logs, maintenance reports and equipment test reports.
- Review station annual budget reports, including maintenance, operations and capital budget reports.
- Collect general plant information as described in Step 4-2.
- Identify risks as described in Step 4-4.
- Input all information into the Data Analysis and Inspection Results Table, Table 4-4.

The results of physical inspections and tests and the interview with plant staff improve the assessment of equipment condition, initiated in Step 4-2. Physical inspections are normally carried out when equipment is operating and generally are limited to a walk-around to obtain a general overview of condition. Equipment is not usually shut down for inspection. If a shutdown coincides with the inspection, more detailed information or condition may be obtained, (though it usually adds to the time required at the site).

During an inspection, any impression on condition is generally based on physical evidence, such as corrosion, leaks, cracks, vibration or monitoring data such as temperature, pressure, vibration etc.

Information retrieved from the inspection, as well as the review of plant information, reports, logs, test data, etc. is entered into the standardized data sheets (Table 4-4) which already includes information gathered from the desktop studies.

Tests may be useful in measuring the degradation of components from the new or re-worked condition, and therefore in estimating the remaining useful life of the component or the time to the next repair. However, testing is often expensive and requires outages so it is usually minimized at this stage, with more extensive testing carried out later, such as during Feasibility.

Volumes 2 to 7 provide guidance for specific tests which may include turbine efficiency, generator and switchgear insulation, resistance or power factor and transformer oil quality. Where specific testing is warranted, the general process is:

- Identify the equipment and characteristics to be inspected and tested.
- Select the procedures for measuring the characteristics.
- Inspect or test the component in accordance with the selected procedure.
- Compare the results with the criteria in the guidelines and with the results of previous tests to identify changes in performance and reliability.
- Estimate degradation and remaining life.

4.4 Identify Risks

The identification of risks, that the hydro plant is exposed to and which relate to life extension and modernization, is an integral part of the Plant Survey process. They fall under three broad categories (Section 2.3.2).

- Business critical risks, which relate to the consequences of catastrophic events.
- Life safety risks, which threaten workers and/or public.
- Financial risks, which relate to equipment failures and misoperation.

These three categories are interrelated. A business critical risk would likely threaten life and could be caused by equipment failures or misoperation. Similarly, life safety risks would likely have severe financial consequences. Each category has a different degree of importance and is normally managed differently.

Hydro utilities and dam owners do not willingly accept significant exposure to business critical risks, the consequences of which would destroy their business. Therefore, every effort is made to identify, manage and reduce the risk appropriately.

Life safety risks, as they affect plant workers, are usually covered by codes and regulations. If these are followed, they would normally result in acceptable levels of safety. Life safety risks to the public either relate to the reservoir/plant accessibility, or to a dam safety incident.

Financial risks, generally tend to have less significant consequences and decisions on mitigation are normally made for business (i.e. economic) reasons.

Step 4-4 only provides a process to identify risks in general terms. Beyond this, it is the responsibility of the hydro plant owner to decide if further risk study is necessary. This could include the prioritization, assessment, evaluation and management of these risks against the risk policy set by the owner. As risk studies can be very complex and as the importance of making good decisions is very high, it is suggested that specialist advice be used, as appropriate.

The risk identification process covers all equipment and structures from "water to wire", using the Asset Register numbering system.

- Dam and reservoir
- Spillways and intakes
- Water passages and conveyances
- Powerhouse structure
- Generating equipment
- Switchgear building

Risk information obtained during the site visit and from the desktop studies are collected in "standardized risk data sheets" so that the information can be entered into the Plant Survey database against the appropriate asset. An example of the risk data sheet is given in Table 4-5.

Columns 1 and 2 identify the component and the associated asset number (Step 4-2). The asset number is used to link identified risk actions to the Needs and Opportunities Table (Step 4-5).

Columns 3 and 4 cover the failure modes for each component. Where no hazardous situations are believed to exist that could cause failure, the remainder of the line is not completed. Column 3 is the hazardous event or situation that could create a failure mode, classified into the following categories:

- Extreme natural event (floods, earthquakes, …)
- Equipment or protection failure
- Security (vandalism, sabotage …)
- Misoperation

Column 4 is then completed by considering "what could happen" given the above hazards. This deals only with an incident that could occur in response to the event, not the severity or probability that it could happen. Usually a one line description is sufficient. Examples would be:

- Wall cracks or collapse
- Embankment slumps
- Gate unable to be closed
- Insulator fails

Column 5 considers the likelihood that the hazardous event and the resulting incident occurs. This can be a very complex issue and while experienced engineers can usually provide an order of magnitude estimate, it is unlikely to be accurate except for very high probability events where

there is a good data base to provide credence to the judgement. For this reason, it is considered prudent to only use a *broad rating index*[12] and err on the conservative side for any risks that have severe consequences.

Columns 6, 7 and 8 cover financial, life safety, and environmental/social consequences, and the *broad rating index*[12] is used for each as appropriate. Included would be both the impacts of failure and any consequential damage to the utility's own property or to others.

Columns 9 and 10 cover risk, in a subjective manner. Risk is normally defined as the product of likelihood of occurrence and the consequences of a failure. At this identification level, it is again suggested that only a *broad index rating*[12] be used.

Column 9 classifies risk in the three categories suggested in Section 2.3.2 of this Guide, namely Business Critical, Life Safety and Financial. Those that fall into the first two categories need to be considered most carefully.

Columns 11 and 12 consider any existing risk management programs or processes that are in place and a ranking of effectiveness for the specific component under consideration.

For example, a general dam safety program will only be considered effective for a particular water retaining structure if the program itself is sound and the inspection, surveillance and treatment of any anomalies are carried out within that program.

Included under risk management would also be:

- detection methods/warning systems
- emergency plans to mitigate consequences
- programs to investigate, identify and fix any identified risks, following a standard program e.g.:
  - fire risk protection program
  - seismic strengthening program
  - oil spill containment
  - fall arrest
  - flood control
  - dam safety
  - maintenance program
  - spare parts inventory

Columns 13 to 17 cover risk mitigation, which is considered necessary if the existing risks appear unacceptable and if existing risk management processes have not dealt with them adequately. This is the most difficult part of the risk identification activity as the output will be a list of potential activities which might be required. They have been identified as areas of concern but there will be no justification at this stage to proceed to implementation. Columns 13 to 17 seek to put them in perspective, identify the activity that may be required and their potential cost and timing.

[12] Each broad rating index proposed for use in risk identification is to be selected by the hydro plant owner. This will allow alignment with the owner's risk strategy.

Table 4-5
Step 4-4: Risk Identification

Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Heading	**Component**		**Failure Mode**		**Likelihood**	**Consequences**			**Risk**		**Risk Management**		**Risk Mitigation (Potential activities, costs and timing)**					**Overall Importance of Risk Issues**
Description **Project**	**Asset No.**	**Equipment, Structure, Other**	**What hazards could occur**	**What could happen**	**How likely is it to happen**	**Financial**	**Life Safety**	**Environmental Social**	**Risk Category**	**Risk Rating**	**Are there processes in place to manage risk/what are they**	**Are they effective**	**Is risk mitigation necessary**	**Will the activity be an Investigation Y/N**	**Will the activity be a Project Y/N**	**What is the approximate Cost**	**What is the likely Timing**	
	From Asset Register		Type of hazard or situation		Rating[1]	Rating[1]	Rating[1]	Rating[1]	Business Critical, Life Safety, Financial	Rating[1]		Rating[1]						Rating[1]

Note 1. Each rating for use in the risk identification will be selected by the hydro plant owner to allow alignment with company risk strategy.

4.5 Identify Needs and Opportunities

The final step of the Plant Survey is the identify needs for life extension and opportunities for modernization.

The primary source will be the completed tables:

- 4-3 Data Analysis for Hydro Plant
- 4-4 Data Analysis and Inspection Results for Equipment and Structures
- 4-5 Identification of Risks

Information from these tables is assessed as to its relevancy and appropriateness and included in the Needs and Opportunities Table. An example of a simplified blank version of Table 4-6 is shown. It is a collation of proposed activities without a thorough analysis to ensure they fit with the plants strategies. (This will take place in Steps 4-6 and 4-7.)

Table 4-6 is also provided in database format for input to the financial model (see Step 4-9). The table covers the entire hydro plant by asset number with activities by year for the next 20 years.

For life extension needs, one table is completed with all the activities noted, their timing (i.e. year(s)) and their estimated cost.

The modernization opportunities are collected in a separate copy of the same table, so that the costs of these activities can be assessed against benefits in the financial model.

Table 4-6
Step 4-5: Needs and Opportunities

Asset No.	Equipment/ Structure (Asset Name and Description)	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per activity per year in PV $																		
								Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Identified Project - Total		x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unspecified Projects - Allowance of 20% of annual average								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Total		x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

4.6 Develop Plant Strategies

Plant Surveys identify the AS-IS situation at a plant. Life Extension and Modernization Plans help the utility decide on the desirable future situation, TO-BE, by aligning what needs to be done with the business objectives of the plant.

Between these two stages there are choices to be made, and plant strategies help with these choices.

Strategies which capture the important decision-making aspects of hydro plant management are:

- Operations
- Workforce and maintenance planning
- Risk
- Product portfolio improvements

Each hydro plant owner needs to select which strategy, criteria and degree of importance to consider. Thus they can balance their utility objectives with technical requirements. This is the first step in optimizing the value of the plant, and will provide reassurance to all decision makers that needs and opportunities will be justified to meet future business objectives.

Prior to developing strategies at the plant level, the overall corporate strategic objectives need to be identified and stated. These will drive development of the plant strategies, which is usually done by the Plant Manager and confirmed with managers responsible for operations and planning. These will then be used to revise the needs and opportunities in Table 4-6 to align with the plant strategies (Step 4-7).

Operations Strategies

A review is first made of the existing product portfolio and the constraints which prevent increasing production of any saleable item. The products are listed and described in Appendix B under Energy, Portfolio Services, Ancillary Transmission Services and Flexible Operation. Constraints include fish water releases, ramping rates, equipment operating limits, rough load zones, minimum/maximum lake levels, other water licence requirements, lack of water, lack of experienced personnel, etc.

The operational strategy reviews the product mix and the constraints, identifies the optimum for each plant, then assesses the opportunity to improve these by reducing or removing constraints.

Operations strategies, which focus on how to make best use of available water, include:

- When to maximize production of energy (at what cost to ancillary services).
- When to minimize variable costs at the expense of production.
- When to maximize availability.

- When to plan maintenance.
- Changes between a wet year and a dry year.
- What other factors are of concern in producing energy (downstream plant, etc.)?
- What is the intended load regime, (stop/start etc.)?
- What will be required from the plant in terms of ancillary services (quantities, period of year)?
- Special site specific considerations on generation.

With the operations strategy for a plant now stated, the importance of the plant and the opportunities for improvement can be better understood.

Workforce and Maintenance Planning Strategies

Maintenance and workforce strategies are devised to ensure competencies are available.

Operating hydro plants is becoming more costly with the escalating cost of skilled labour. This is especially true for a plant which is staffed 24 hours per day with all the incurred loadings for overtime and special rates. An attractive option may be to automate the plant and reduce the operating workforce, with all the resultant effects on the design of the new and rehabilitated equipment. If automation is to be part of modernization then provision of adequate telecommunications and security for the plant is necessary.

Maintenance costs are also escalating. However, even with maintenance-free elements and condition monitoring in the modernized plant, some human intervention will always be required. Costs can sometimes be reduced by innovative practices such as roving maintenance teams operating to a regular routine or sharing staff with other parts of the organization or different organizations.

Condition monitoring, either by manual collection or by automatic data acquisition system is gaining increasing importance. It can be used to decrease maintenance activity and hence cost as well as give warning of critical situations.

Strategies include:

- How to attract and retain competent workforce?
- What core skills need to be retained and/or developed?
- Factors involved in contracting.
- How to fill out the ‘quiet’ periods of the year:
- offer contracting services to local industry,
- share staff with other facilities.
- Factors to include when deciding to minimize outage times.

- Optimum balance of planned versus unplanned outages - (reductions in planned maintenance increase risk)
- How to decide on maintenance intervals (time based or condition based)?
- Which part of the year to use for maintenance outages?
- What trends to monitor, what level of condition monitoring to select?
- How to make decisions on replacement versus ongoing (and increasing cost) maintenance?
- Standardize equipment in plant and between plants to reduce spare parts inventory.

Risk Strategies

Prior to considering additional expenditures at a plant, whether for life extension or modernization, the plant owner is encouraged to identify and manage risk exposure (the concept is similar to that of an insurance company). This can be achieved by identifying and understanding the risks, ensuring that the range of plants is broad enough so that all risks do not eventuate at once and maintaining suitably sized reserves to cover the risks that do eventuate. Initially it is necessary to establish all requirements of compliance, and the plants position in meeting them. There are also the business risks - risk of lost revenue or lost assets. These risks need to be categorized (into equipment grouping) and assessed (number of causes, probability of occurrence(s), consequences). The plant owner will then decide if they are over exposed and define any risk reduction strategies to be followed (e.g. fire protection upgrade programs, etc.).

Developing risk strategy includes:

- Identifying risks
- Evaluating consequences
- Evaluating probabilities
- Determining risk policy
- Optimizing level of risk exposure
- Managing risks through risk reduction programs
- Who has responsibility for which risks?

Once the strategies are defined the needs for and benefits of investment in risk reduction can be addressed.

Product Portfolio Improvements

The electrical system into which the plant is feeding will no doubt have increased in size and reliability since the plant was installed. What could well have been one of the largest and more important assets in the system may now be a minor element. Present contribution to system frequency control might now be insignificant and declining. Load patterns may have changed in

the intervening years together with the need for power factor correction. It is here that the special attributes of hydro power deserve investigation. Modernization could be the opportunity to change the plant from base load to peaking operation. If synchronous condenser operation and spinning reserve are not included in the current modes of operation, it may be possible and justifiable to consider modification to allow these operations. This is especially pertinent where the unit is to be automated and de-staffed and fast start up can easily be accommodated. If many components have to be replaced and storage facilities permit, conversion to a pump storage unit may possibly be justified (though this would probably be considered a redevelopment option).

Having documented all management policies and strategies for the plant, it is important to optimize the product portfolio. First, the market needs are analyzed (the market may be the transmission grid and system operator) by establishing what is needed and determining what opportunities exist for increases. This can be done:

- at the expense of other products (portfolio optimization)
- through improved practices or investment

Portfolio optimization requires a good understanding of values and costs of the individual products. Then, the overall effect of improvements of one at the cost of another can be evaluated. The value of a product is two fold:

- Market value. What will the market pay?
- Shareholder value - is it of value to the shareholder (e.g. long-term return, goodwill, etc.)?

Once it is established that the increased product is of value and saleable, the means to create the increase have to be established. The strategies are reviewed to identify opportunities to improve and test these with specific new equipment and methods.

Ways to improve product portfolios are contained in Appendix B to this Volume.

4.7 Align Needs and Opportunities with Plant Strategies

Using Table 4-6 as a master list of needs and opportunities, appropriate projects for life extension and modernization are identified. These cover all plant assets and align with Plant Strategies.

Figure 4-2 shows how the projects are aligned, modelled and selected for the Modernization Plan.

Life Extension (Needs) Projects

As input to the Life Extension Plan, the following methodology is suggested:

- Separate out "regular maintenance projects" that are: a) predictable, b) usually performed on an annual or biennial basis, and c) included in most years under the typical annual maintenance budget. These projects are not selected as they are usually included in the plant annual maintenance plan. In the financial analysis, the maintenance plan costs are added to the estimate of capital projects.
- Only include projects that are over $20k for large plants, (annual O&M > $0.75 million), and over $10k for smaller plants. However, if there are many below these limits, an allowance can be made or a sensitivity analysis performed to determine a lower limit on project size.
- Include equipment replacement projects. The replacement cycle for smaller equipment often falls between 5 and 20 years.
- Include significant maintenance overhauls or rehabilitation projects that definitively extend the asset's life.
- Include projects that maintain the level of service and the range of products offered by the plant.
- Include projects that deal with significant risk issues by managing the current level of risk exposure for the plant.
- Include projects that facilitate operational changes which reduce wear and tear on plant equipment and thus extend the plant's service life.

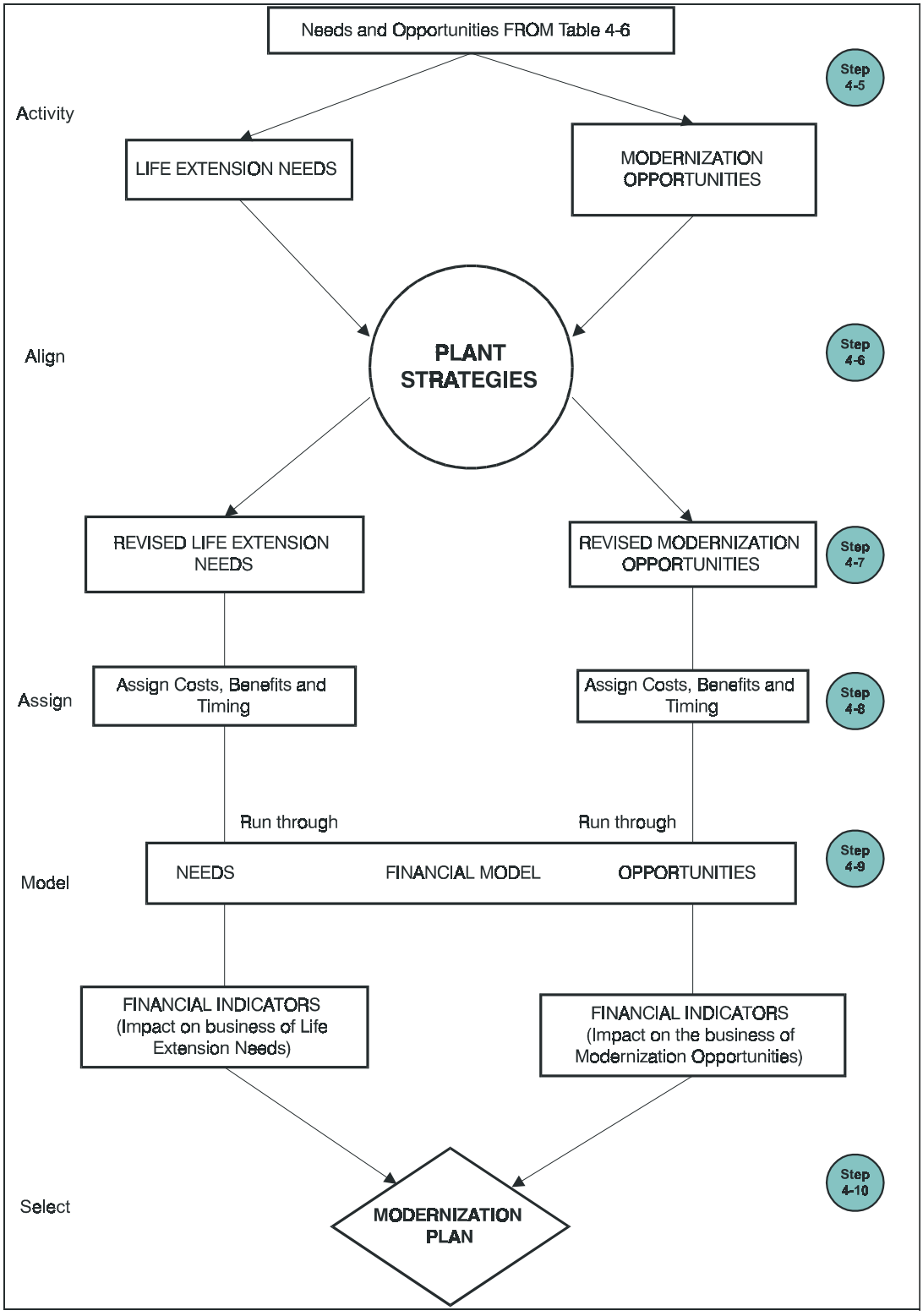


Figure 4-2
Step 4-7: Development of Modernization Plans

Modernization (Opportunity) Projects

Modernization opportunities at the equipment and plant level:

- add to or improve upon the mix of products and service offered by the plant.
- reduce the plant's risk level below its historical level.
- improve plant profitability (increase revenues or decrease costs).

Modernization opportunities are identified by plant managers/personnel and the assessing engineers knowledge or research into new technologies and operational practices.

Some examples are included in the following box:

CATEGORY	TYPICAL INVESTMENT	TYPICAL BENEFIT
O&M Review	• Plant Automation (Controls Upgrade)	• Reduced Operating Costs • Improved Dispatchability • Improved Water Use (Efficiency)
Dispatch Strategies/ Operating Constraints	• Plant Automation (Controls Upgrade) • Regulatory Application • Increased Maintenance	• Improved Output or Dispatchability • Increased Generation or Dispatchability • Reduce Forced Outages
Runner Upgrade	• Runner, Generator rewind, Transformer, Governor, etc.	• Increased Generation and/or Output

Justification and Alignment with Strategies

Each hydro plant owner has their own procedures for selecting and justifying expenditures, but in all cases justification parameters need to be clearly presented. This normally takes the form of financial rate of return, benefit/cost ratio or net present value of marginal cost, so that the benefits associated with each opportunity can be evaluated.

Modernization opportunities have to align with the strategies for improvement. One way to show this is through preparation of a link sheet. Table 4-7 is an example which shows the alignment of expenditures with the strategy and the strategy with corporate objectives. Once prepared, this link sheet provides a quick visual confirmation of exposure (objectives or strategies without planned expenditure) or unbalanced effort (too many projects focused on one strategy or strategic objective).

Table 4-7
Step 4-7: Strategies/Opportunities Link Sheet

UTILITY STRATEGIC OBJECTIVES	PERFORMANCE INDICATORS	PLANT STRATEGY	MODERNIZATION PROJECTS
1. Utility strategic objective(s) on Investment			
2. Utility's strategic objective(s) on market share			
3. Utility's strategic objectives on risk management			
4. Utility's strategic objectives on stakeholder interests			
5. Utility's strategic objectives on organization and culture			

Licensing and Environmental Consideration

Options available to reduce the risk or cost of licensing and to manage environmental issues are included in Technical Volumes 2 to 7. These include new technologies and operational changes, including:

- Reduce monitoring costs (e.g. automation, batch data collection etc.).
- Improve the accuracy of monitoring.
- Reduce risk exposure of a plant by early detection, emergency plans, back-up systems etc.
- Change in plant operation to meet or exceed regulatory obligations.

Costs and benefits are usually evaluated at the feasibility level as environmental issues tend to be complex and site-specific.

Revision to Needs and Opportunities Table

Having filtered the needs and opportunities so that they align with the plant strategies (and this can be done effectively in a facilitated workshop environment) the selected projects are included in a revised version of Table 4-6, shown here as Table 4-8.

Table 4-8
Step 4-7: Needs and Opportunities (Revised To Align With Plant Strategies)

HYDRO PLANT NAME _____																								
Asset No.	Equipment/ Structure (Asset Name and Description)	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per activity per year in PV $																
								Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Identified Project - Total		x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unspecified Projects - Allowance of 20% of annual average								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Total		x						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

4.8 Assign Costs, Benefits, and Timing to Selected Needs and Opportunities

In Step 4-8, costs, benefits and timing are assigned for the activities listed in the revised Table 4-8. These costs, benefits and timing form the basis of input to the financial model (Step 4-9).

Costs

Cost estimates for Life Extension and Modernization Plans will be commensurate with the accuracy of the information used in the Plant Survey. At this overview level, cost estimates will be in the range of ±35% for civil components and ±20% for equipment.

The team selecting and assessing activities and projects will prepare estimates to within these ranges and with the appropriate price contingency, based on the average costs of labour and materials for the work proposed.

Cost estimating will generally follow the process discussed in Section 2.3.3, namely:

- Engineering judgement.
- Experience with similar equipment and projects and historical maintenance and capital planning data.
- Technical Volumes 2 to 7 which provide cost data on replacement and rehabilitation work, based on age and condition of the equipment and improvement opportunities.

For the 20 year planning horizon, cost estimating accuracy is more important in years 1 to 5. Costs in subsequent years are substantially discounted when their present value is used.

A further 20% contingency is suggested on the sum of all projects in a particular year to account for oversights in identifying projects that will eventually be found necessary.

A sensitivity analysis can be performed to determine the effect of cost estimating accuracy on the financial indicators calculated (Step 4-9).

Benefits

All products sold to market or transferred to other business units are identified. Their value is established using company standard methods (market predictions, transfer prices, etc.). Life extension and modernization benefits are evaluated in the same way. Present value with a 20 year window is used, though other time durations can be selected. All financial and non-financial benefits are collected and used in comparisons and optimization. Benefits from equipment improvements are addressed in Volumes 2 to 7.

Timing

Timing of life extension needs includes the following considerations:

- Schedule activity based on plant survey assessment of end of life. This uses:
  - historical maintenance records,
  - plant personnel opinions,
  - visual inspection,
  - life cycle and asset decay curves in Volumes 2 to 7.
- Adjust timing to coincide with other plant initiatives, (e.g. replacement of a protection device may be redundant if an upgrade of the protection and control system is scheduled in the next 5 years).
- Schedule activities to levelize costs and labour requirements.
- Aggregate work to reduce costs and minimize maintenance.
- Schedule activities for periods that minimize the value of lost generation.
- Schedule activities to maximize risk avoidance or reduction.

The timing of modernization opportunities is usually based on achieving any improvements:

- at the earliest possible time.
- when the market exists for the improvement.
- when the financial resources are available.

Where modernization opportunities are significant, e.g. major unit upgrade or uprate, timing can allow testing the first unit installed prior to the next installation. This will confirm results and allow corrections and improvements.

4.9 Complete the Economic/Financial Evaluation

Purpose of the Evaluation

Data concerning the performance of the plant has been collected to date but no overall assessment of the present or future value plant has yet been made. In order to conduct the assessment, for the purposes of these guidelines, an example of an electronic evaluation template is provided with the guidelines. The template (hereafter referred to as the Model) has been designed to meet the following objectives:

- value the short and long-term profitability and cash flows of individual hydro plants; and
- review the impacts on profitability and cash flows resulting from modernization options.

To meet these objectives, the Model that has been developed for the guidelines provides the following information:[13]

- Income and cash flow statements for an individual hydro plant, for the life extension plan for up to a 20 year period.
- Income and cash flow statements for the same individual hydro plants' modernization options that are incremental to its life extension plan.
- Income, cash flow and benefit/cost analysis capability for an individual project.

The Model uses net present value and benefit cost ratios as the primary measures of a project return. It does not include other generally accepted measures such as economic or shareholder value added. The choice of measure for assessing project return is an individual one for each user of the guidelines and will not be covered here.

The Model has been designed and provided as an example of an evaluation methodology. The Model does not represent the prescribed methodology of EPRI or BC Hydro International.

Model Design

The Model has been designed to forecast up to 20 years of results. Forecast results are presented in both financial and economic terms; financial results are presented in income statement format where economic results are presented in cash flow format.

Figure 4-3 provides an overview of the information and data required to use the Model. The utility using the Model is responsible for their own data collection and data entry. The Model calculates results based on input provided by the user.

Model Limitations

The Model does ***not*** make decisions. The Model provides information to enable the review of potential impacts on certain decision criteria. Specifically, the decision criteria that the Model provides are income, cash flows (real and discounted), return on assets, and benefit-cost ratios.

Following are explicit limitations of the Model:

- *risk:* the Model does not incorporate risk analysis; there is no explicit capability to address benefits arising from reductions in probabilities of failure. However, reductions in O&M or investment costs, increases in revenues, avoided risk costs, or avoided lost revenues, can be used as proxies for the value of changes in probabilities of failure.
- *impacts on strategic, social or environmental initiatives:* The Model has not been designed to quantify impacts on issues that are non-financial or those that are difficult to meaningfully quantify. However, the financial results provide information from which inferences can be made with respect to critical or implicit values.

[13] The model provides information on an individual hydro-plant to the level of operating income, prior to non-plant overhead allocations, and excluding income tax effects. The model is based on definitions as provided in Part 101 of the Federal Power Act, Subchapter C - Accounts.

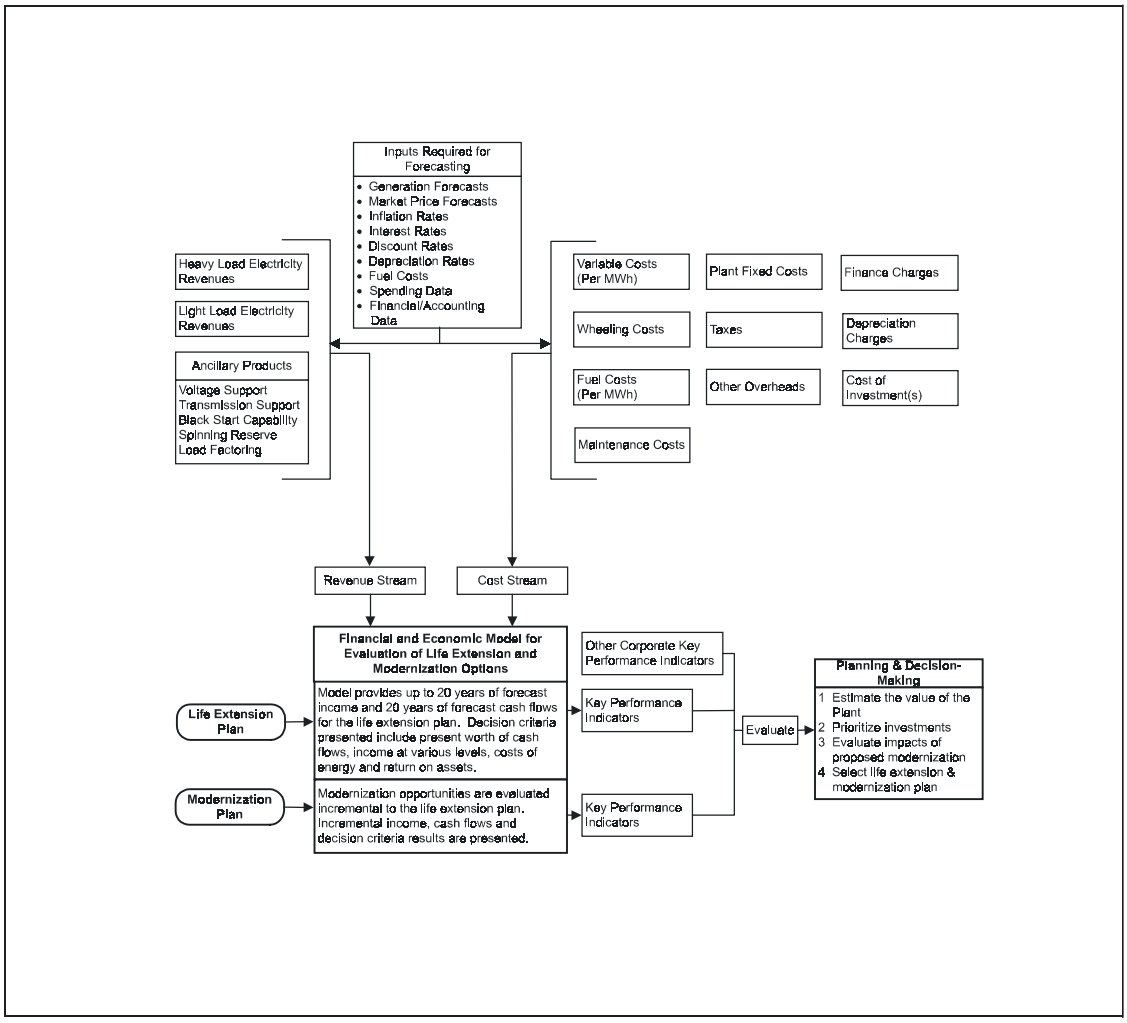

Inputs Required for Forecasting
Generation Forecasts
Market Price Forecasts
Inflation Rates
Interest Rates
Discount Rates
Depreciation Rates
Fuel Costs
Spending Data
Financial/Accounting Data
Heavy Load Electricity Revenues
Light Load Electricity Revenues
Ancillary Products
Voltage Support
Transmission Support
Black Start Capability
Spinning Reserve
Load Factoring
Variable Costs (Per MWh)
Plant Fixed Costs
Finance Charges
Wheeling Costs
Taxes
Depreciation Charges
Fuel Costs (Per MWh)
Other Overheads
Cost of Investment(s)
Maintenance Costs
Revenue Stream
Cost Stream
Financial and Economic Model for Evaluation of Life Extension and Modernization Options
Model provides up to 20 years of forecast income and 20 years of forecast cash flows for the life extension plan. Decision criteria presented include present worth of cash flows, income at various levels, costs of energy and return on assets.
Modernization opportunities are evaluated incremental to the life extension plan. Incremental income, cash flows and decision criteria results are presented.
Life Extension Plan
Modernization Plan
Other Corporate Key Performance Indicators
Key Performance Indicators
Key Performance Indicators
Evaluate
Planning & Decision-Making
1 Estimate the value of the Plant
2 Prioritize investments
3 Evaluate impacts of proposed modernization
4 Select life extension & modernization plan

Figure 4-3
Process and Data Flow of the Electronic Evaluation Template

Forecasting the Economic/Financial Value of Plant Life Extension

Collecting Input Assumptions

Prior to using the Model, it is recommended that the utility collect the following data:

- *Generation Forecasts:* acquire a monthly generation forecast of energy production that distinguishes between heavy load hour generation and light load hour generation. The Model notes two types of generation forecasts, gross energy and net energy. Gross energy represents total energy generated, where net energy represents energy generated that is available for sale. The utility needs to gather monthly forecasts of energy that will be consumed by the plant (to operate the plant) as heavy load and light load. The generation forecast has to reflect load growth, operating constraints and average in-flow conditions.

- *Market Price Forecasts:* acquire monthly market price forecasts of value of electricity that distinguishes between heavy load hour and light load hour generation.
- *Economic Indicators:* the Model incorporates the following economic indicators:
  - Discount rates: used to calculate the present value of cash flows. Typically, this is equal to the utility's weighted average cost of capital.
  - Blended interest rates: used to calculate finance charges for presentation on the income statement. Interest rates modelled represent the blended average cost of short-term and long-term borrowing rates.
  - Inflation rates: used to incorporate inflation, if the utility prefers to use nominal dollars. It is necessary for the user to distinguish between nominal and real dollars. If nominal and real dollars and discount rates are interchanged, inaccurate computations will result.
- *Life Extension Spending Forecast:* the spending forecast includes O&M and capital dollars. Spending forecasts are driven by the plant survey and documented in the Needs and Opportunity Table 4-6. Spending forecast data includes:
  - Project/activity name: a description of the project and tasks to be completed.
  - Asset number: the asset number that the costs are assigned to.
  - Forecast spending: identification of the amount of spending expected to complete this activity in each of the next 20 years. Some projects, depending on life cycle, will be repeated within the 20 year time horizon. The spending forecast captures all spending for all anticipated projects. Spending includes a contingency and common overhead charges.
  - Spending has to be designated as either capital or O&M.

Populating the Model

After the input assumptions have been collected, the Model is populated. Table 4-9 provides summary level information on what data is required to be entered into the Model, where and in what format. A user manual is supplied with the Model.

Table 4-9
Step 4-9: Populating the Model

Table (Screen) in the Model	Calculated or Manual Data Entry	Data to be Manually Entered into the Table	Format of Data Entry
Generation Data	Both	• Monthly Heavy Load Hour Gross Generation	MWh
		• Monthly Light Load Hour Gross Generation	MWh
		• Monthly Heavy Load Hour Generation Consumed by the Plant	MWh
		• Monthly Light Load Hour Generation Consumed by the Plant	MWh
Market Prices	Manual	• Monthly Price of Heavy Load Hour Electricity	$/MWh
		• Monthly Price of Light Load Hour Electricity	$/MWh
		• Monthly Loss Factors	%
Economic Indicators	Manual	• Weighted average cost of capital or the prescribed discount rate	%
		• Forecast blended interest rates	%
		• Forecast inflation rates	%Δ
Accounting and Financial Data	Manual	• Net book value of the facility at the beginning of the first fiscal year being modelled	$ 000
		• Composite depreciation rate of the facility based on the most recently completed fiscal year	%
		• Forecast value of other revenues	$ 000
Other Assumptions	Manual	• Identify year zero (the first year of the forecast)	Whole No.
		• Determine if the model is using real or nominal dollars (inflation on or off)	Yes or No
		• Select the depreciation rate to be used:	Click Icon
		• Declining Balance = 1; Straight-line = 2	
Life Extension Spending Forecast: O&M	Manual	• Enter the O&M forecast for each year	$ 000
Life Extension Spending Forecast: Capital	Manual	• Enter the Capital forecast for each year	$ 000

Reviewing the Results

Results are calculated after the Model has been populated and when the user requests to view a report. To review and analyze the results, the user can either print or view the results on screen. The Model includes the following four reports:[14]

- Maintain Existing Service Level Income and Cash Flow Statement
- Spending Forecast Reports which can be sorted by dollars or project type
- Modernization Income and Cash Flow Statements
- Incremental Modernization Income and Cash Flow Statements. The modernization statements are presented incremental to the "maintain existing service levels" option.

To view a report, the user "clicks" on the icon that denotes the report required. The database automatically displays reports prior to printing. After the report has been viewed, click on the print icon for a printed copy.

Forecasting the Economic/Financial Value of Plant Modernization

Generating Modernization Options

The Modernization Plan, as it relates to the Model, provides forecast income and cash flow statements reported as incremental to the life extension plan or in the aggregate. The Modernization Plan is the result of modifying (accelerating, deferring or deleting) life extension projects and/or adding new improvement projects, and identifying the impacts of project modification or addition.

To develop a modernization plan, the following steps are recommended:

- Identify projects that present opportunities to modernize the plant. Projects can be selected by reviewing opportunities in the areas of:
  - equipment replacement.
  - maintenance overhauls or rehabilitation.
  - opportunities to modify the level of service, nature of service or range of products.
  - risk reduction.
  - facilitate operational changes that reduce wear and tear on plant equipment to such an extent that they significantly improve the plant's profitability.
- Identify the effects of modifying a life extension project or adding a new project. Impacts identified will include increased energy/efficiency, reduced long-run (or short-run) maintenance costs, improved reliability, etc.
- Update the Life Extension Project Modification screen of the Plant Modernization Project screen as prompted.

[14] Experienced Access Database users can create ad-hoc reports as required.

As with the life extension options, to view a report, the user “clicks” on the icon that denotes the report required. The database automatically displays reports prior to printing. After the report has been viewed, click on the print icon for a printed copy.

4.10 Document Life Extension and Modernization Plan

The objectives of a Life Extension and Modernization Plan are to:

- Optimize the life cycle of plant assets and plan for their timely rehabilitation or replacement (life extension).
- Identify methods to improve the financial prognosis of those plants rated as having the most potential to improve (modernization).

Documentation of the results of this process is important so that:

- Records are kept of the plant survey results.
- Records are kept of the needs and opportunities which match the plant strategies.
- Basis of modernization evaluation is recorded for later project justification.
- Framework for ongoing improvements and updates is in place.

A lot of data and information will be collected to develop the plant survey results. It is suggested that this is filed, but only the pertinent results included in the Plan. This will be the contents of:

- Table 4-3 - Data Analysis Table for Hydro Plant.
- Table 4-4 - Data Analysis and Inspection Results for Equipment and Structures.
- Table 4-5 - Risk Identification.
- Table 4-6 - Needs and Opportunities.

Plant Strategies for the important decision-making aspects, are included written specifically for each plant:

- Operations
- Workforce and Maintenance Planning
- Risk
- Product Portfolio Improvements

Table 4-7, Strategies/Objectives Link Sheet, confirms that the modernization activities are aligned with plant strategies and company strategic objectives.

Table 4-8 includes the Needs and Opportunities, revised to reflect Plant Strategies.

Documentation of the Plan is completed with the results of the economic/financial evaluation which summarize the effects of life extension and modernization projects on the plant.

This allows the projects that are most needed and most attractive to be compared with others in the plant owners portfolio. Those that receive the highest rating can be taken to Feasibility and probable Implementation.

4.11 Review Life Extension and Modernization Plan

Measuring Results

The overall objectives of life extension and modernization are to maximize the value of the portfolio of hydro plants and meet the requirements of stakeholders.

In each case there needs to be a clear process in place to measure results. This in turn requires indicators to measure and tools to measure them with. This will allow utilities to know how well they are doing while allowing corrections and improvements. This measurement feedback must be timely, accurate and meaningful to be useful and promote these continuous improvements.

There are four parts to measuring results:

- What variables measure performance?
- Are the processes in place for measurement?
- Is measurement being done?
- Do the measurement results confirm that improvements in performance are being achieved?

Performance

Many assumptions are made in preparing the Plan, especially as this an overview level assessment. The Plan is dependent on the outcome of these assumptions, but is made flexible enough to reflect those that prove incorrect. The Plan is long-term and many of the investments occur over an extended period, or are repetitive. Therefore, the Plan needs to continually measure and report on performance. If an apparent improvement turns out to be ineffective, this important information can help avoid similar mistakes at other plants.

There are two reasons to measure performance; evaluate increases in profitability and ensure that the performance claimed by manufacturers or contractors is realized.

To evaluate increases in profitability, the net plant capacity and availability needs to be measured before and after modification. Similarly, to evaluate the performance of plant components, the output, losses, consumption and availability (as applicable) of each plant component to be modified, is measured before and after modifications.

Monitoring Requirements

Monitoring equipment is needed to measure performance. The expected improvement and its value are established, the means of measurement is determined and the necessary equipment put in place. Regular reporting and linkages to any similar work proposed or already installed, contribute to the assessment of performance.

Updates of Strategies and Plans

Performance reports are used to assess the effectiveness of the selected activities by investigating their impact on the relevant strategies. For instance, if work to improve a particular operational strategy is found not to have the expected positive effect on overall profitability, the strategy is deemed ineffectual and is revised.

Also, as assumptions are proved or disproved over time, the Plan will require updating. Annual updates are suggested. Any work or predictions that did not occur in that year will either be moved on to the next year or eliminated.

The overall intent is to continually manage the asset, deal with expected and unexpected occurrences, manage change in the market and react quickly to improve profitability. This change management and continuous improvement are reflected in the utility's strategies.

5
APPROACH FOR MULTI-PLANT PORTFOLIO

The approach that utilities take to make choices between plants in a system or portfolio is not explicitly covered in the Guidelines. However, it is an important business consideration and a discussion on the key issues involved is appropriate.

This section provides a general overview and description of the processes and information needs that can be used to develop the optimal investment strategy for an overall portfolio of plants. Initially, the information provided for individual plants on life extension and modernization can be ranked based on the needs of the entire portfolio. Competitive financial criteria can be used, as well as environmental and social impacts, strategic impact and implementation risk. A number of tools to help rank the opportunities are identified.

Information provided for each plant in their Life Extension and Modernization Plans provides the key input to the ranking process. Commercial information, in the form of specific criteria for each utility, supports the ranking process. Processes and tools which can be used to prioritize stakeholder requirements and assist in managing investment/divestment decisions are identified.

The overall process that can assist the user in selecting the optimum investment activities, from the entire portfolio of assets is shown on Figure 5-1.

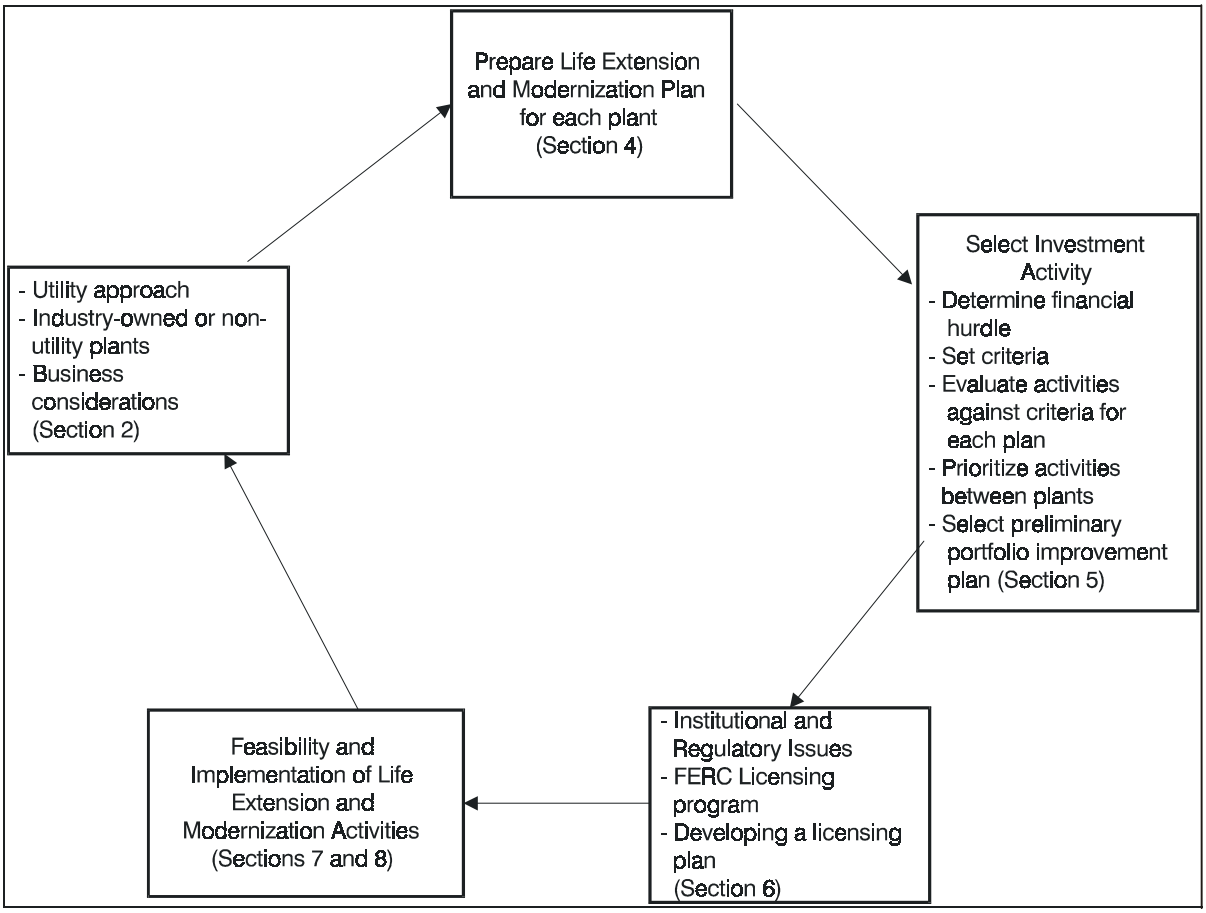

Prepare Life Extension and Modernization Plan for each plant (Section 4)
Select Investment Activity
- Determine financial hurdle
- Set criteria
- Evaluate activities against criteria for each plan
- Prioritize activities between plants
- Select preliminary portfolio improvement plan (Section 5)
- Institutional and Regulatory Issues
- FERC Licensing program
- Developing a licensing plan (Section 6)
Feasibility and Implementation of Life Extension and Modernization Activities (Sections 7 and 8)
- Utility approach
- Industry-owned or non-utility plants
- Business considerations (Section 2)

Figure 5-1
Selecting and Prioritizing Life Extension and Modernization Activities

5.1 Purpose

The purpose of reviewing individual Life Extension and Modernization Plans in the context of the overall portfolio is to:

- ensure that the investment resources of the utility are directed to the areas where maximum long-term benefit can be gained.
- benchmark “value for money” across several plants.
- optimize the product portfolio for the utility to meet, but not surpass, market needs.
- avoid competition for product supply between owner’s plants.
- promote project approval in a portfolio framework rather than on individual basis.

Along with a review of the project financial aspects, many utilities and dam owners consider a wide range of benefits which are of importance to a range of stakeholders. The principle of Value Based Management (VBM) is often used to achieve this.

VBM is a process to consider and balance a full range of interests. It can include Strategic Impact, Financial Benefit, Environmental Benefit, Compliance Needs, Goodwill (public, employees, ethnic), Safety, Social Benefit, Costs, Implementation Risk (see Table 5-1).

5.2 Process

Select Investment Alternatives

For easy consideration, Life Extension and Modernization projects are classified into three categories:

- Mandated Projects are those that maintain or meet compliance requirements and are carried out as a first priority (Dam safety improvements normally are in this category)
- Life Extension Needs Projects (low financial risk) restore or maintain the existing level or cost of service
- Modernization Projects (higher financial risk) raise the level of service or lower the cost of service

Life Extension Needs and Modernization Opportunity projects will always require economic evaluation and justification.

Initially, the life extension and modernization activities for all plants are identified by year, by cost and by basic economic parameter (say Benefit/Cost Ratio). These activities can then be assessed against any basic hurdles that the utility may apply. This usually relates to the availability of capital funds.

Those activities that meet or exceed the hurdle can then be prioritized further. Those below the hurdle are normally considered in subsequent years, reassessed to improve their attractiveness or discarded/replaced with others.

By considering all plants in a portfolio, the impacts of any one on another are addressed.

The next step groups the projects based on the benefits they provide. They can then be reviewed with regard to product ‘expansion’ needs, based on market supply/demand.

In this way, all projects or activities across the portfolio of plants can be grouped and ranked by:

- Market needs
- Funding requirements

Those that meet market needs and are within funding allowances can be evaluated using a process such as VBM.

Criteria

Section 2 discussed the criteria that can be used in the evaluation of life extension and modernization decisions and which reflect the objectives and values of the hydro plant owner.

These criteria are the basis of the VBM approach. For weighting and scoring purposes, they can be separated into four groups:

- Strategic Impact
- Benefits
- Costs
- Implementation Risk Factors

Table 5-1 shows a number of criteria under each group. However, each utility can select which are of importance to itself, based on its own values and needs. These criteria are normally selected to reflect the utility's performance indicators.

In the example shown, weightings are applied between the four groups (divided by W, X, Y and Z) and other weightings can be applied to each of the criteria. A score is then given to each criteria. Again the weightings and scoring methods are made by the utility to meet its own business requirements.

The final step is the summation of scores for each project which allows a weighted total to be established and used for ranking and prioritization. This process is sometimes referred to as the "Balanced Score Card Approach".

Tools

A process such as VBM with the utility's own values assigned to each criteria, can be enhanced by available software.

Tools that can be used for decision support range from basic spreadsheets for the more straightforward all the way to commercial software products for more complex choices.

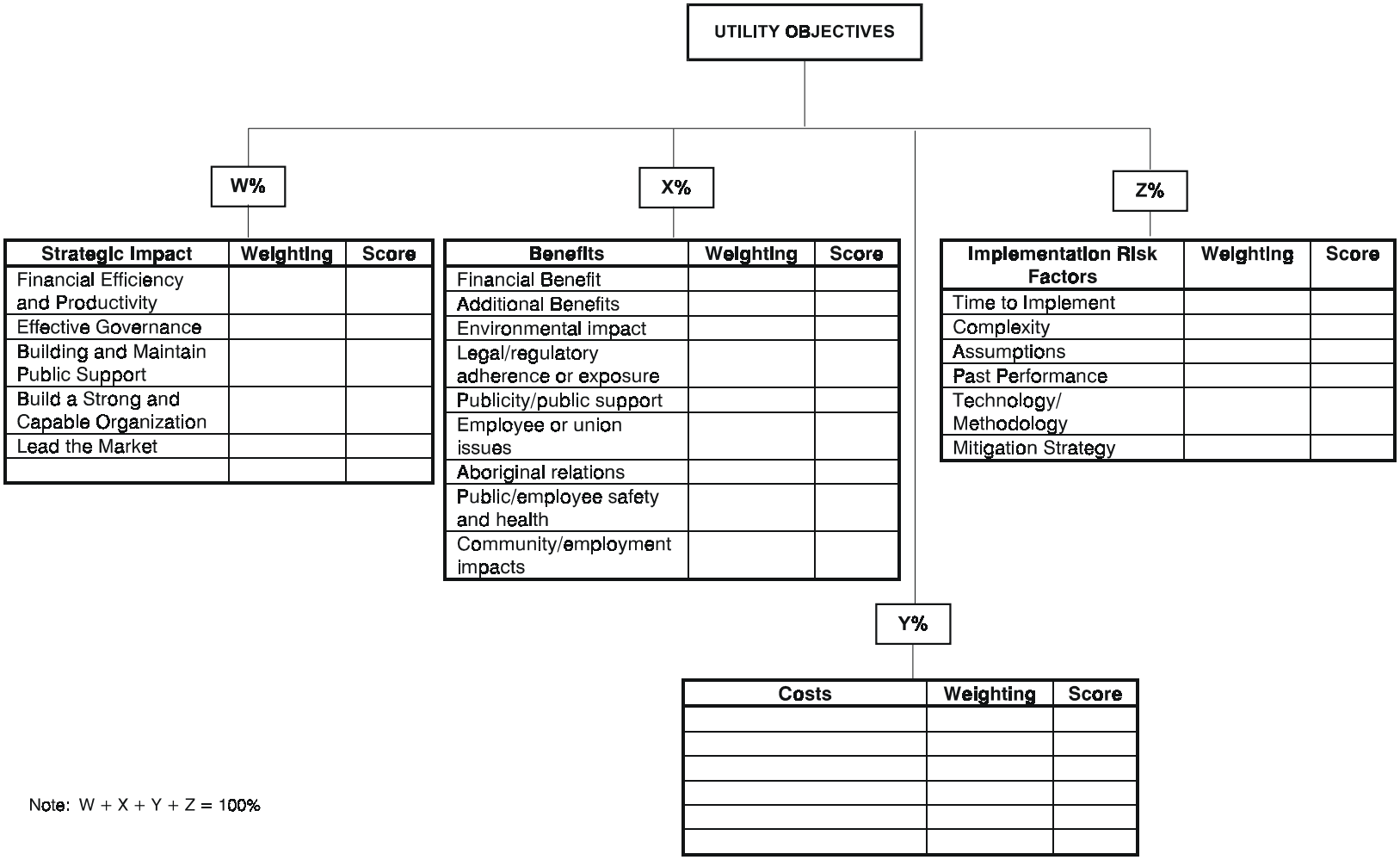
Examples of commercial software that has been used for this process includes:

- Expert Choice, Decision Support Software

5.3 Implementing and Managing Investment Activities

Life extension and modernization is an investment in the future of the utility. Therefore, in addition to making the best decisions, it is critical that these be implemented successfully, quality assurance be in place, the results be measured and improvements made to the process where required.

Table 5-1
Examples of Criteria for Ranking Life Extension and Modernization Activities



Strategic Impact	Weighting	Score
Financial Efficiency and Productivity		
Effective Governance		
Building and Maintain Public Support		
Build a Strong and Capable Organization		
Lead the Market		

Benefits	Weighting	Score
Financial Benefit		
Additional Benefits		
Environmental impact		
Legal/regulatory adherence or exposure		
Publicity/public support		
Employee or union issues		
Aboriginal relations		
Public/employee safety and health		
Community/employment impacts		

Implementation Risk Factors	Weighting	Score
Time to Implement		
Complexity		
Assumptions		
Past Performance		
Technology/ Methodology		
Mitigation Strategy		

Costs	Weighting	Score

Note: W + X + Y + Z = 100%

6
INSTITUTIONAL AND REGULATORY ISSUES

6.1 Introduction

Purpose and Scope of Section

This section provides an overview of institutional and regulatory (I/R) issues for the USA only. Its purpose is to identify typical issues and how they affect planning and decision-making for modernizing a hydro plant. However, the general concepts can be used for similar issues outside of the USA.

Why Institutional and Regulatory Issues are Important?

Today, institutional and regulatory issues are, in most cases, the least certain factors in the planning of hydro development including modernization projects. Whereas hydropower is a mature technology that has proven reliable in terms of performance and cost, I/R issues are often difficult to define, complex in nature and uncertain in terms of cost, time and outcome.

Modernization may present an opportunity to address existing licensing or compliance issues (e.g. adding flow-meters to improve control of in-stream flow releases) and/or may raise new issues (e.g. in-stream flow impacts due to change in operation). It is therefore very important to understand both existing and potential I/R issues in planning, decision-making and implementation processes.

The project's licensing status is an important issue that needs to be considered early in a modernization analysis because:

- The existing licence and FERC's regulations may limit the modernization options available.
- The expiration of the existing licence may limit the time available to recover the cost of the modernization investment.
- The need to relicense the project because of the impending expiration of the existing licence may precipitate the modernization plans.
- In some instances, the modernization may change the overall licensing classification of the project requiring either changes in licensing conditions or filing of an application for a new licence.

Failure to give early consideration to these issues can lead to problems further down the road including:

- Flawed decision-making.
- Unforeseen permitting/licensing delays.
- Unforeseen permitting or mitigation costs.
- Alienation of agencies and stakeholders that should be involved up-front.
- Changes in overall project regulatory classification requiring reconsideration of licensing issues and new licence terms and conditions.
- Reopening of controversial issues that may have already taken much time and many resources to resolve.
- Re-negotiation of settlements, special use permits or operating agreements.
- Unforeseen water rights issues.
- New constraints that may not have previously existed and may affect any future operations.
- New safety and performance criteria that may be more stringent than existing criteria.

In summary, because modernization of a project involves change, and change creates regulatory exposure, it is important to identify I/R issues early in the planning process and to address them in decision-making and implementation.

How to use this Section

An overview of the hydropower licensing process is followed by a discussion of licensing issues that affect modernization of hydro plants. A guide to screening and ranking projects according to licensing factors is provided. Section 6 concludes with a generic step-by-step approach to developing a licensing plan.

Much of the information has been summarized from information for licence applicants, provided by FERC. Because the hydropower licensing process is complex and continually evolving, users of this information have to use up-to-date information on regulatory requirements. Current FERC regulations are published in the Code of Federal Regulations at 18 CFR Subchapter B Part 4. Further information and assistance can be obtained directly from staff at FERC's Division of Licensing and Compliance. FERC staff can also provide information regarding other federal statutes that may apply. State regulatory requirements are also important and are acquired from government agencies.

6.2 FERC Hydropower Licensing Program

Who is FERC?

The Federal Energy Regulatory Commission (FERC) is an agency of the federal government. FERC's overall regulatory jurisdiction is as follows:

- Licensing and regulating non-federal hydroelectric projects.
- Regulating transmission of natural gas, oil and electricity in interstate commerce.
- Overseeing related environmental matters.
- Administering accounting and financial reporting requirements of utility and other companies subject to FERC regulation.

The Federal Power Act (FPA) provides the FERC with the exclusive authority to license non-federal waterpower projects on navigable waterways and federal lands.

FERC is composed of five members appointed by the President with the advice and consent of the Senate. One member is designated by the President as Chairman and serves as FERC's administrative head.

FERC's Office of Hydropower Licensing, headquartered in Washington, D.C. is responsible for administering the hydropower program. The Office consists of two divisions:

- ***Division of Licensing and Compliance*** processes and analyzes applications for preliminary permits, licences (including re-licences), and exemptions, monitors compliance with terms and conditions, takes actions to ensure compliance, and evaluates applications for amendment of licence and other proposed project modifications.
- ***Division of Dam Safety and Inspections*** supported by staff in regional offices located in New York, Atlanta, Chicago, San Francisco, and Portland (Oregon), carries out the dam safety and public safety programs and assists in ensuring compliance with licence terms and conditions.

Brief History of FERC

Before passage of the Federal Water Power Act[16] in 1920, developers needed a special act of Congress to build and operate a hydroelectric power plant on navigable streams, or federal lands. Congress had authorized construction of the first hydroelectric project in 1884.

Demand for electric power suddenly increased during World War I. In 1920, Congress responded to this demand by enacting the Federal Water Power Act, which established the Federal Power Commission (FPC). Composed of the Secretaries of War, Agriculture, and the Interior, the FPC was responsible for licensing non-federal hydroelectric power projects that affect navigable waters, occupy federal lands, use water or water power at a government dam, or

[16] Federal Water Power Act now known as the Federal Power Act codified in USC 791a-825r.

affect the interests of interstate commerce. The Act also required the FPC to license only those projects that in its judgment were *"...best adapted to a comprehensive plan for improving or developing a waterway or waterways...."*

Besides meeting the growing need for electric power by establishing an orderly means for developing hydroelectric power, the Congress also wanted to protect the public interest in the use of a national resource-streams and rivers-for power generating purposes. In its first 2 years, the FPC received 321 applications involving the construction of about 15 000 MW of new generating capacity more than three times the capacity of then existing water power projects.

In 1930, FERC was reorganized as an independent Commission composed of five members appointed by the President with the advice and consent of the Senate. In 1935, Congress amended and recodified the Federal Water Power Act of 1920 as Part I of the Federal Power Act. This legislation extended the FPC's authority to regulate the interstate aspects of the electric power industry.

In the Department of Energy Organization Act of 1 October 1977, Congress created the Federal Energy Regulatory Commission and abolished the FPC. FERC inherited most of the work done by the FPC, including the licensing of non-federal hydroelectric power projects.

In more recent times the act has been amended to address growing environmental aspects of regulation. On 16 October 1986, Congress passed the Electric Consumers Protection Act (ECPA), which amended the Federal Power Act. Major changes to FERC's hydroelectric power program included:

- Eliminating municipal tie-breaker preference in re-licensing and establishing new procedures for processing re-licence applications to increase opportunities for agencies, interested organizations, and the public to participate in the process;
- Requiring FERC to base its recommendations for mitigating adverse effects of a licensing proposal on the recommendations of federal and state fish and wildlife agencies and to negotiate with the agencies if disagreements occur;
- Requiring FERC to give the same level of consideration to the environment, recreation, fish and wildlife, and other non-power values that it gives to power and development objectives in making a licensing decision; and
- Giving authority to issue compliance orders and assess civil penalties up to $10,000 per day for violations of rules, regulations, and terms and conditions of licence or exemption.
- On 24 October 1992, Congress enacted the National Energy Policy Act, which affected FERC's hydropower program as follows:
- Prohibits licencees from using the right of eminent domain in parks, recreational areas, or wildlife refuges established under state law;
- Allows applicants for licence to fund environmental impact statements referred to as third-party contracting; and
- Authorizes FERC to assess licencees for costs incurred by fish and wildlife agencies and other natural and cultural resource agencies for studies required under Part I of the Federal Power Act.

FERC's Role in Hydropower Regulation

The two main areas of FERC jurisdiction that impact modernization of hydro plants are its licensing program and its dam safety program. It is important that the relationship of these programs to modernization of hydro plants is well understood so that their regulatory requirements can be fully addressed.

Licensing Program

Federal hydroelectric power projects are authorized by Congress and constructed primarily by the U.S. Department of the Interior (Bureau of Reclamation), the U.S. Army Corps of Engineers, and the Tennessee Valley Authority. These projects do not come under FERC jurisdiction.

For most non-federal hydroelectric power projects, the Federal Energy Regulatory Commission must issue a licence authorizing construction, or in the case of an existing project, continued project operation.

FERC issues ***original licences*** for hydroelectric projects for periods up to 50 years. When a licence expires, FERC may issue a ***new licence*** (i.e. re-licensing) to the original licencee, or to a new licencee. In the event that the licence is awarded to another licencee the new licencee must acquire the necessary property rights and equipment from the original licencee.

For certain types of small hydroelectric projects, FERC also issues ***exemptions*** from licensing which are issued in perpetuity.

Original Licences

The Federal Power Act requires that an owner obtain a licence or a licensing exemption from FERC before constructing, operating, or maintaining a hydropower project which meets any of the following criteria:

- Located on a navigable waterway of the U.S.;
- Occupying U.S. lands;
- Utilizing surplus water or water power from a U.S. government dam; or
- Located on a body of water over which Congress has Commerce Clause jurisdiction, project construction occurred on or after 26 August 1935, and the project affects the interests of interstate or foreign commerce.

A licence application can be filed by any citizen, association of citizens, domestic corporation, municipality, or State. For the term of the licence, typically 50 years, the licencee is granted permission to construct operate and maintain the licensed project subject to the terms and conditions of the licence.

There are five categories of project as follows:

- ***Major Unconstructed Project*** any unlicensed water power project that would:
  - have and installed capacity of more than 1.5 MW; and
  - use the water power potential of a dam and impoundment, which, at the time the application is filed, have not been constructed.
- ***Major Project-Existing Dam*** a licensed or unlicensed, existing or proposed water power project that would:
  - have a total installed generating capacity of more than 2000 hp (1.5 MW); and
  - not use the water power potential provided by any dam except an existing dam.
- ***Major Modified Project*** any ***major project-existing dam*** that would include:
  - any repair, modification or reconstruction of an existing dam that would result in a significant change in the normal maximum surface area or the normal maximum surface elevation of an existing impoundment; or
  - any change in existing project works or operations that would result in a significant environmental impact.
- ***Major Water-Power Project 5*** megawatts ***or less*** a major project-existing dam, major unconstructed project, or major modified project that has a total installed capacity of 5 MW or less.
- ***Minor Water Power Project*** any licensed or unlicensed, existing or proposed water power project that would have a total installed generation capacity of 2000 hp (1.5 MW), or less.

These categories determine the scope of the exhibits and documentation required to support a new licence application or capacity-related amendment to an existing project. In a case where the modernization would change the classification of an existing project then additional documentation consistent with the new classification may be required.

New Licences (Re-Licences)

When a licence issued to a private entity (for example a private utility, a manufacturing company, or an individual) expires, FERC may issue a new licence (commonly known as re-licensing) to the original licencee, or to a new licencee.

FERC may also recommend federal takeover, if it determines that such action would better serve the public interest (however, this has never occurred.) If a federal agency recommends takeover of a project, FERC postpones its decision for 2 years to give Congress time to consider the recommendation. Licensed publicly-owned (i.e. owned by states, cities, irrigation districts, or water conservation districts) projects are not subject to federal takeover.

At least 5 years before a licence expires, the existing licencee must file a notice of intent declaring whether or not it intends to seek a new licence for its project. At least 2 years before a licence expires, the licencee must file an application for new licence.

Competition for a project licence is allowed during all new licence proceedings. When the FERC receives one or more acceptable applications for a new licence, it reviews and then evaluates the proposal(s) within the procedural framework of the National Environmental Policy Act (NEPA), and according to a set of factors established by the Electric Consumers Protection Act (ECPA).

The FERC must evaluate and balance the various public interest issues to ensure optimum utilization of the waterway for beneficial public purposes. FERC must also find that the licencee:

- Can comply with the terms and conditions of a new licence,
- Can manage and operate the project safely,
- Can operate the project to provide efficient and reliable service,
- Can demonstrate its need for project power,
- Has adequate existing and proposed transmission facilities, and
- Will operate and maintain the project in a cost-effective manner.

Also, in the case of an application by an existing licencee, the FERC will consider the following:

- The existing licencee's record of compliance with the terms and conditions of the existing licence, and
- Actions taken by the existing licencee related to the project that affect the public.

Exemptions

The FERC exemption process simplifies the filing and review requirements for certain types of small hydro projects. Those receiving an exemption are exempt from the requirements of Part I of the Federal Power Act. Exemptions are issued in perpetuity, are made subject to mandatory terms and conditions set by federal and state fish and wildlife agencies and by FERC, and they do not convey the right of eminent domain.

There are two types of exemptions:

- ***Small Project Exemption:*** This applies to small hydropower projects, which are 5 MW or less, that will be built at an existing dam, or utilize a natural water feature (e.g. a waterfall or sloping reach of stream) for hydraulic head.
- ***Conduit Exemption:*** This type is issued for a hydropower project on an existing conduit (e.g. irrigation canal, or aqueduct). Authorized generating capacity must be 15 MW or less for a privately owned project and 40 MW or less for a publicly owned project. The conduit has to have been constructed primarily for purposes other than power production and be located entirely on non-federal lands.

Dam Safety

Dam safety is a critical part of FERC's hydropower program and affects modernization of projects that involve dams. In terms of number of projects (dams) inspected approximately 3036 FERC's dam safety program is the largest in the federal government. Moreover, over two-thirds of these dams are more than 50 years old. As dams age, concern over their safety and integrity grows and oversight and a regular inspection program are extremely important.

Before new projects are constructed, FERC reviews and approves the designs, plans, and specifications of dams, powerhouses, and other structures. During construction FERC engineers frequently inspect a project, and after construction is completed, inspect it on a regular basis, often every year. These inspections: verify the dam's structural integrity; identify needed maintenance and remedial modifications; ensure that projects are properly maintained; and verify that licencees comply with the terms and conditions of their licences. Inspection visits are coordinated with resource agencies, state dam safety officials, and other interested agencies. FERC staff also inspects projects on an unscheduled basis to investigate: potential dam safety problems; complaints about constructing and operating a project; safety concerns related to natural disasters; and issues concerning compliance with the terms and conditions of a licence.

A licencee must retain an independent board of consultants to review the design and construction of major or complex hydropower projects. Every 5 years an independent consulting engineer, approved by FERC, must inspect and evaluate projects with dams higher than 32.8 ft (10 m), or with a total storage capacity of more than 2000 acre-ft (2.5 million cubic meters). The board identifies any actual or potential deficiencies that might endanger public safety and FERC requires the dam owners to correct them.

There is concern that seismic events will affect dams; therefore, FERC retains the services of consultants to assist the commission's staff in addressing this issue at specific dams. Also, FERC staff monitors and evaluates seismic research in geographic areas where there is concern over possible seismic activity. This information is applied in investigating and performing structural analyses of hydroelectric projects in these potentially affected areas.

FERC, in a continuing effort, evaluates the effects of potential and actual large flood events on the safety of dams. During and following flood events, FERC staff visit dam sites, determines the extent of damage, if any, and directs any necessary studies, or remedial measures the licencee must undertake.

With respect to modernization projects, the need to bring dams up to contemporary safety standards is frequently a stimulus for modernizing the facility. Two frequent issues are increasing spillway capacity to meet forecasted extreme flood events and additional structural stability to meet seismic safety standards. Another recent issue is upgrading gates and valves to address safety issues and provide for partial evacuation of the reservoir in case of an emergency.

FERC Licensing Processes

FERC's licensing regulations have evolved over the past 78 years to meet changing public and institutional needs. In the past three decades, the main emphasis has been on addressing environmental issues in keeping with their growing importance.

Today the FERC licensing process is one of the nation's most thorough environmental review and regulatory processes. Due to the high cost and large amount of time required to acquire a licence via the traditional FERC process, new processes are being explored with a view to meeting regulatory requirements more efficiently. The following sections briefly describe the traditional process and some recent variations.

Traditional Process

Preparation of Application

Before submitting an application for licence or exemption, a potential developer must follow the requirements in the pre-filing consultation process outlined in FERC's regulations. Under this process, a developer must complete a three stage agency consultation process as follows:

- ***Stage 1*** - Applicant issues an Initial Consultation Document
  - Holds Joint meeting with agencies, tribes and others
  - Receives comments and study requests
- ***Stage 2*** - Applicant conducts studies
  - Provides draft application to agencies, tribes, others
  - Receives comments
  - Holds joint meeting to resolve issues
- ***Stage 3*** - Applicant files licence application with FERC
  - Application sent to agencies and available to public

The licence application comprises a series of exhibits that address the engineering, environmental and financial aspects of the project. Engineering exhibits describe the recommended project design concept supported by results of site investigations, hydrologic analyses, project design, dam safety studies, energy generation projections, operation and maintenance plans, cost estimates, construction schedules and information regarding financial aspects of the project.

The environmental exhibit is usually the largest component of the application that describes the potential effects of the project on fish, water availability and use, water quality, wildlife, botanical resources, geology, soils, botanical resources, recreation, historic resources, land use, and socioeconomic values. This exhibit also includes proposed mitigative, protective and enhancement measures.

Preparation of a licence application via this process normally takes from 1 to 3 years depending on the size and complexity of the project.

Processing

After an application is filed, FERC gives the public and interested organizations and government agencies further opportunity to participate in the licensing process. Also, before FERC staff prepares an environmental document under the provisions of the National Environmental Policy Act and FERC's regulations, they issue scoping documents and often hold scoping meetings. The scoping process enables interested agencies, organizations, and local citizens to help FERC in:

- Identifying significant issues,
- Determining those issues requiring and not requiring detailed analysis,
- Determining the depth of analysis required for each issue, and
- Identifying appropriate alternatives to consider.

FERC may prepare an environmental document (i.e. environmental assessment or environmental impact statement or sometimes both) on a single project or several projects, both existing and proposed, in a river basin. In all cases, FERC addresses any cumulative effects (combined effect of all proposals and existing projects) that would occur to the area's resources.

Before issuing a licence, FERC must determine if a proposed project is "best adapted to a comprehensive plan for improving or developing a waterway or waterways" for beneficial public uses. Among other things FERC must consider is the extent to which a project is consistent with federal or state comprehensive plans for improving, developing, or conserving a waterway or waterways affected by the hydroelectric project. Also, FERC must weigh the competing interests, including both power and non-power uses, to ensure a proper balance is struck between developmental and non-developmental interests in any licensing decision.

Licence Issuance

In any licence issued, FERC includes terms and conditions (called licence articles) that are requirements a licencee must comply with to keep the licence in effect. These requirements usually address engineering, environmental, operation and administrative matters.

Processing of an application via the traditional process can take from as little as several months for an amendment, to 1 to 2 years for a straightforward new licence, and up to a decade or more for projects with very complex environmental or legal issues. In the case of existing projects where the original licence has expired and issuance of a new licence is delayed, FERC may issue an Annual Licence as an interim measure.

After a licence is issued, the FERC monitors the licencee's compliance with the licence conditions throughout the term of the licence.

Alternative Processes

FERC regulations provide for several alternative approaches to licensing including:

- The Applicant Prepared Environmental Assessment (APEA) Process.
- Third Party Contracting.
- Hybrid processes using collaborative teams, settlements, alternate dispute resolution and mediation.

On 29 October 1997, FERC issued order No. 596 revising its procedural regulations governing applications for licences and exemptions of hydro projects. The regulations offered an alternative process whereby in appropriate circumstances the pre-filing consultation process and environmental review process can be combined. These regulations supplemented existing regulations rather than deleting or replacing them.

Alternative APEA Process

In this process[17] the applicant prepares a draft Environmental Assessment in lieu of the Exhibit E (Environmental Report) in the traditional process. The draft EA is filed with FERC along with the other project exhibits that comprise the licence application.

The goal of the process is to:

- Expedite the licensing process.
- Front load NEPA review and other requirements by providing oversight for an applicant who prepares a Draft Environmental Assessment (DEA) during the pre-filing consultation period.
- Facilitate a process where the DEA fully evaluates and balances the interests of all stakeholders involved.

Table 6-1 shows a comparison of the traditional process and the APEA process. The table shows the front-loading resulting in fewer post-submittal licensing activities and a shorter application processing time.

[17] On 22 June 1998 FERC issued specific guidelines for the Applicant Prepared Environmental Assessment (APEA) Process

Table 6-1
Comparison of Traditional and APEA Licensing Processes

TRADITIONAL	APEA
PRE-FILING CONSULTATION	
Process Selection	
• Applicant develops consultation mailing list	• Work Group Formation • Setup Communications Protocol • APEA Request
Stage One	
• Applicant Issues ISCD • Joint Meeting 30-60 days later - Comments and Study requests due 60 days after meeting	• Applicant Issues ISCD / SDl • Joint Meeting/Scoping Meeting SD2 • Comments and Study requests due 60 days after meeting
Stage Two	
• Applicant Conducts Studies • Applicant Provides Draft Licence Application to Agencies, Tribes, and others • Comments due to applicant in 90 days –Applicant holds joint meeting within 60 days of comments if there is substantive disagreement on issues	• Applicant Conducts Studies • Issue request for Additional Studies ~Scoping (if not completed in stage one) • Draft EA Document Prepared • Request Preliminary Recommendations and Comments • Joint meeting if substantive disagreement • Final Licence Application and EA Prepared
Stage Three	
• Applicant files Licence Application with FERC • Application mailed to agencies and made • Available to public	• Applicant files Licence Application and EA • Application and EA mailed to agencies and made available to Public
LICENCE PROCESSING	
Application Acceptance	
• FERC issues public notice that application has been filed • Additional study requests are due within 60 days • Commission Staff reviews application for adequacy • Commission issues public notice that application is accepted • Protests and interventions due 60 days after notice	• FERC issues public notice accepting Application, Requesting Interventions, and Requesting Final Terms and Conditions • Comments due 60 days after notice
NEPA Scoping • Commission Staff prepares scoping document • Staff conducts scoping meeting • Comments due 30 days following meeting • Staff determines need for additional information • Commission issues notice that the application is ready for Environmental Review • Comments due 60 days after notice	**NEPA Document Preparation** • Staff prepares and issues draft EA or EIS • Comments due 30-45 days later • Commission initiates 10(j) negotiation process if needed • Staff issues final EA or EIS **Commission Action** • Commission issues licensing decision order • Parties have 30 days to file for rehearing
NEPA Document Preparation • Staff prepares and issues draft EA or EIS • Comments due 30-45 days later • Commission initiates 10(j) negotiation process if needed • Staff issues final EA or EIS	
Commission Action • Commission issues licensing decision order • Parties have 30 days to file for rehearing	

Benefits of the APEAs process include:

- Reduces the application processing time at FERC.
- Combining the NEPA and other statutory processes in the pre-filing process the applicant has more direct interaction with the project review and decision-making process.
- FERC staff is involved earlier resulting in more comprehensive scoping of studies and fewer post-filing additional study information requests.
- The applicant is able to gauge all participants (i.e. including FERC) positions on issues much sooner than in the traditional process.
- Reduces regulatory uncertainty and delay.
- Increased speed helps avoid staff turnover in all participants.
- Potential for more creative and effective environmental protection/mitigation solutions.

Possible disadvantages of this process are:

- Potentially more up-front time and expense.
- Not all projects or participants suited to a consensus based process.
- May break down if any major stakeholder is either left out of process or later decides to abandon or attack the process.
- Gives more interested parties the opportunity to request studies and mitigation without any economic incentive or accountability to avoid wasting resources.
- More difficult to protect proprietary information in more open process.
- For an amendment it may be difficult to keep process focused on the limited issues at stake.

The APEA process is best suited to projects where there is a strong likelihood of maintaining a functional consensus between the applicant and most interested parties throughout the process.

Third Party Contracting EIS

In the third party environmental impact statement (EIS) process, the NEPA process is expedited by selecting a third-party contractor to prepare the Draft Environmental Impact Statement (EIS) either during licence application preparation or after the application is submitted. The contractor is funded by the applicant.

In this approach the applicant avoids post licence application filing delays associated with staff availability and budget constraints within FERC. Conflict of interest safeguards and exparte communication protocols are established to maintain the integrity of the process.

The main advantage of this process is time. The main disadvantage is that the applicant has less control over the process and the exparte communication protocols are less conducive to problem solving and consensus building processes involving all parties.

Because most of the Environmental Assessments produced for hydro projects by FERC follow the form of a mini-EIS then it is also possible to use the more open APEA process to develop a draft EA which can later be expanded by FERC or a third party contractor into a full EIS-if necessary.

Other Hybrid Processes

Other processes may evolve or be adopted for a particular project to meet the special needs of the project and the participants involved.

A typical example is a hybrid process where the applicant commences an APEA process but later falls back to the traditional process due to lack of consensus and progress using alternative process. Another such process may be where one or more applicants in a river basin undertake some form of joint process to expedite licensing and jointly address stakeholder issues.

The FERC licensing process is a living process that is continually evolving. New variations on the traditional and alternative processes are likely to evolve as participants search for more efficient ways to address the underlying issues in the best public interest.

Amendment Process

Introduction

Licence and exemption amendments are generally required when there is a proposed change to a project previously authorized by a FERC licence or exemption. Most major modernization proposals on FERC licensed hydro projects that do not coincide with re-licensing will require an amendment to an existing licence or exemption[18].

A key element of the amendment process is early contact with FERC staff. The licencee contacts the staff regarding any proposed modification to the project that affects the terms and conditions of the licence or exemption. If the licencee is uncertain about what steps to take, staff can provide advice.

[18] More detailed information on the amendment process can be found in the Code of Federal Regulations (18 CFR §4.200) and in the FERC publication Guide to the Hydroelectric License and Exemption Amendment Process March 1992.

When is an Amendment Needed?

Most project changes that require an amendment can be classified into six categories:

- ***Capacity Changes*** - An increase or decrease in project capacity from that licensed will trigger a licence amendment. The primary licensing concern is any related environmental impacts that may not be addressed in the original licence. Increases in plant electrical output capacity of 2 MW or more, and maximum hydraulic capacity of 15% or more are regarded as capacity-related amendments.
- ***Design Changes*** - Modernization may involve significant changes to the physical features of a project, such as new structures, relocation of transmission lines or alterations to existing structures. Common design changes include increases in dam height, modifications to transmission lines or routes, installation of fish ladders or fishery enhancement structures, construction of afterbays and the addition of flashboards to a spillway.
- ***Operational Changes*** - As part of modernization plans an owner may wish to change the way a project is operated, such as change the maximum or minimum operating level in the reservoir, change the minimum in-stream flow requirement, or change the flow ramping rate.
- ***Land Status Changes*** - Modernization plans may require changes in the project boundary or changes in use of project lands. Such changes may include expansion of the project boundary to address changes in impoundments, relocated facilities and new facilities.
- ***Compliance Filings*** - In any licence or exemption issued by FERC, certain terms and conditions are included. These conditions are referred to as “articles.” Articles require a licencee or exemptee to adhere to requirements that may govern project operation, require monitoring studies, or address a variety of issues related to environmental effects and engineering. Modernization of some facilities may render some of these requirements obsolete and require modifications to licence articles.
- ***Time extensions*** - This type of amendment seeks to extend the time limit for commencement of construction or compliance with a time-related article in the licence.

Plant modernization activities generally fall in one of the first three categories.

Types of Amendment

There are two basic types of amendment:

- Capacity-related
- Non-Capacity-related

FERC defines capacity-related licence amendments as changes in a hydropower project that involve additional capacity not previously authorized, and that:

- Would increase the actual or proposed total installed capacity[19] of the project;
- Would result in an increase in the maximum hydraulic capacity[20] of the project of 15% or more;
- Would result in an increase in the installed nameplate capacity[21] of 2 MW or more.

Changes in capacity that do not meet all of the above criteria are considered to be **non-capacity-related amendments**.

Amendment Applications

When a licencee proposes to change a project five key questions need to be addressed?

- Does the change constitute a modification of the licence?
- Is the change capacity-related?
- Which exhibits need to be filed?
- Is the modification substantial or would property holders be affected?
- Is an environmental assessment required?

There are two main types of amendment: capacity-related and non-capacity-related.

A ***capacity-related amendment*** involves an application and review process similar to that of an original or new licence except that the review is focused on the proposed modifications to the project. The traditional process typically involves:

- 3-Stage pre-filing consultation.
- Preparation of formal application.
- Public notice.
- Environmental review process.
- Preparation of a NEPA Document.
- Agency recommendations and mandatory conditions.

An alternative process such as the APEA process is well suited to capacity-related amendments.

[19] The installed capacity is the sum of the nameplate capacities of all the generating units in a hydroelectric project.
[20] The maximum hydraulic capacity is the maximum water flow rate that can be discharged simultaneously through all the project turbines for generation at any time.
[21] The nameplate capacity of a generating unit is the manufacturer's rating of the generator as printed on the unit.

A ***non-capacity amendment*** is less involved and includes the following:

- A letter to FERC describing the purpose and scope of the amendment including relevant correspondence from resource agencies.
- Submittal of amended licence exhibits.

6.3 Other Permits, Licences and Agreements

Clean Water Act

Section 401 of the Federal Clean Water Act prohibits a federal agency from issuing a permit or licence for a project involving a discharge to waters of the U.S. unless the project's discharge has been certified not to cause water quality standard violation. This certification is usually issued by the state's water quality control agency.

Although the certification is usually obtained without difficulty, the issues, which arise in obtaining the certification, are not always limited to water quality concerns, but may involve other water-related issues, such as fish passage. Concerns about water quality in bypassed stream segments (minimum flow releases, DO levels, etc.) also occasionally cause problems. If the water quality certification is denied, FERC and other federal agencies cannot issue any approval for the project.

Wetlands Permits

A Section 404 permit from the US Army Corps of Engineers (Corps) is required for any dredge or fill activities in waters of the US. Usually, any new construction in a river or reservoir requires a dredge and fill permit. The concerns and issues involved in issuing the dredge and fill permit are essentially the same as those discussed in the FERC proceedings.

Special Use Permits

Projects that occupy national forest lands normally require a special use permit that contains conditions of use. Such a permit may have requirements regarding land use, construction practices, access, and operation of a project that may impact a planned modernization project.

State and Local Permits

State and local permitting requirements vary across the country, and therefore must be established based on project location.

Many states have their own environmental permitting process which must be addressed as part of project licensing. In some cases, state permitting processes are addressed jointly with the FERC process and in some other cases they may be addressed separately.

State fish and game agencies often have permitting requirements aimed at protecting species and habitat during construction activities. State historic resource agencies may also have permitting processes designed to protect historic resources and archaeological sites.

In many states, water rights are an important issue that also must be addressed. Water rights may limit the storage, diversion, and types of use or place of use of streamflow. Many streams in the west are fully appropriated for water storage or supply at various times of the year therefore any proposal to change water use requires careful consideration. In some cases a water rights hearing is held to resolve competing demands.

Agreements

Many existing multi-purpose hydro projects have agreements in place regarding water storage, water supply, flood control, project operation, shared use of facilities, etc. that must be carefully considered when modernizing a project. It is important to know the status of each agreement and in particular what the possible outcomes of re-negotiation may be.

In some cases, existing agreements may have favorable terms that may be partially or fully lost if the agreement is reopened. In other cases, the modernization project may provide a new opportunity to resolve issues in an unsatisfactory agreement.

6.4 Typical Licensing Issues

Several environmental issues are prevalent in re-licensing, licence amendment, and exemption proceedings at FERC.

If disputes arise over these issues between the resource agencies and the owner or FERC, recent re-licensing legislation directs FERC work toward developing a compromise acceptable to all parties. If such a compromise is not possible, FERC is obligated to accept the resource agencies' recommendations unless such recommendations are inconsistent with the Federal Power Act. As a result, resource agency recommendations carry considerable weight and form the basis for some FERC licence conditions.

The following sections briefly discuss licensing issues that may affect modernization projects.

"Best Adapted" Comprehensive Development

FERC has the responsibility to determine that the proposed modernization of the hydropower project is "best adapted" to a comprehensive plan for improving or developing the waterway. This determination often involves balancing competing uses of the waterway for such diverse uses as hydropower generation, waste load allocations, recreation, minimum streamflows for aquatic habitat, municipal/industrial water supply, etc.

Many of these competing uses are changing with time; therefore anything that triggers a reassessment of comprehensive development may change the portion of the available resource allocated for project use. Before reopening this issue, owners should be aware of comprehensive

plans and how they may affect the existing project. In cases where there is growing demand in other use areas these competing uses should be factored into the modernization plan to identify potential impacts. An example may be diversions upstream of the project for irrigation and water supply. Increases in population and water use may precipitate a future reduction in streamflow available for power generation that may affect future generation and plant upgrading potential.

Resource Utilization

In re-licensing proceeding FERC requires the applicant for a new licence to demonstrate that it is making good use of the hydropower resource in the public interest. Often the applicant will prepare a resource utilization study to demonstrate the history of resource utilization, and study potential additional use of the resource through life extension, modernization or redevelopment.

Balancing of Power and Non-power Values

In deciding whether to issue a new licence or re-licence a project FERC gives equal consideration to a full range of licensing purposes related to the potential value of a stream or river. Among these purposes are:

- hydroelectric development
- energy conservation
- fish and wildlife resources, including their spawning grounds and habitat
- visual and aesthetic resources
- cultural resources
- recreational opportunities
- other aspects of environmental quality
- irrigation
- flood control
- water supply

Changing times and societal values may change this balance for a particular project. It is important to weigh these issues carefully and offer solutions that both provide balance and maximize the value of the project within resource constraints.

Cumulative Impacts

Occasionally, there may be several projects proposed within a single watershed. Whenever this situation occurs, the cumulative effects of the projects must be considered. This analysis may indicate that, although each individual project has acceptable effects on the watershed's resources, the projects interact synergistically or cumulatively to produce significant overall adverse effect within the watershed.

In such cases, either one or more of the proposed projects must be modified to reduce such cumulative impacts. This issue is important where there are several existing projects in a watershed either owned by one party or by several parties. Linkages between the projects must be understood so that changes proposed in any one project do not create I/R exposure for one or all of the remaining projects or precipitate a re-evaluation of all projects.

Streamflow Impacts

Impacts on streamflow or water quality often conflict with optimal operation of the project. In many cases the existing operation plan including instream flow releases or ramping rates has been arrived at through considerable studies, consultation with agencies and negotiation with affected parties. This needs to be taken into consideration when contemplating a change. In some cases the changes may be a win-win for the owner and other stakeholders and in other cases the risks of reopening this issue may overshadow potential gains from improving or upgrading the plant.

Evaluation of this issue requires a thorough understanding of competing interests at stake. Depending on the potential impacts, anticipated changes may require instream flow, fish, wildlife and riparian vegetation studies to provide a basis for a new flow regime.

Water Quality

Water quality issues may include impacts of impoundments on physical quality, chemical quality, dissolved oxygen or water temperature.

If the project modifications will significantly reduce spillage over a dam, the agencies become concerned about the effect of the project on downstream dissolved oxygen (DO) concentrations. Often, the owner must commit to monitoring downstream DO levels after commercial operation of the project begins. Additionally, the Owner must agree to enhance DO levels if the monitoring program shows inadequate DO concentrations downstream. Effective DO enhancement measures may include the use of air injection into the draft tube or self-venting turbine runners.

Water temperature is also a critical factor for downstream fish habitat. Many newer projects now include special multi-level intakes to control water temperature downstream. In many cases retrofitting a multi-level intake to an operating reservoir is difficult without substantial drawdown and associated loss of generation.

Sedimentation is another factor that may need to be considered. Some more recently licensed projects include flushing flows to maintain the stream channel in a bypass reach of river. Where possible, provision should be made to maintain the natural migration of sediment downstream. Accumulation of sediment in forebays and afterbays becomes a liability because it reduces available storage and may be very expensive to remove in accordance with environmental constraints designed to protect downstream fish habitat.

Another water quality issue which may arise during the licensing of the modernization of the hydro plant is the minimization of oil contamination potential. This issue would involve assuring the regulatory agencies that the modernization of the hydro plant includes appropriate design

changes to eliminate or minimize potential sources of oil contamination. Such measures may include rerouting powerhouse drains to a single sump equipped with an oil/water separator and an effluent hydrocarbon monitor or installation of containment curbs/berms around oil storage areas/tanks with controlled drainage.

Fishery Impacts

If the project is located on a fairly productive aquatic habitat, fish impingement or entrainment losses become a concern. Entrainment losses can be minimized by low approach velocities in the headrace or by using fish screens having small spacing. However, intake screens often result in fish impingement losses unless approach velocities are kept very low. Reducing approach velocities to very low levels can be prohibitively expensive because of the large intake area required. Consequently, the owner and agencies must quantify the anticipated losses and agree on mitigation measures for the fish losses.

For those projects located on streams having anadromous fish, or which are targeted for anadromous fish restoration efforts, the concern is the need for downstream and upstream fish passage facilities. The problems of incorporating such facilities in the project design are often compounded by the need to supply sufficient flows to attract fish to the fish passage facilities rather than to the turbine intake/tailrace.

Wildlife

Potential wildlife impacts include destruction of habitat, disruption of food supplies interference with migration routes or effects on reproduction. In many cases these impacts have already been addressed as part of initial development of the project and incremental impacts due to modernization are small in comparison. However, these potential impacts and therefore constraints should be carefully identified and evaluated to determine any significant constraints associated with impacts to important resources such as threatened or endangered species.

Threatened and Endangered Species (TES)

Preservation of threatened and endangered species is an important issue. New species listings occur as more is known regarding species populations and in response to new factors that challenge species survival.

Again it is important to keep track of species listings and habitat restoration plans to determine potential effects on existing and upgraded projects. In cases where a project adversely affects a TES species it will be difficult to permit any changes to the project that don’t seek to reduce or minimize impacts. In some cases there is strong sentiment to decommission projects that endanger TES species. This should be kept in mind when considering other options including modernization.

Geology and Soils

Key issues include impacts of any new construction on slope stability and soil erosion. These impacts can be short-term such as impacts due to construction activities or more long-term impacts such as slope stability impacts stemming from changing water levels in an impoundment or changes to streambed morphology caused by changes in operation regime. Generally project changes that result in potential soil erosion, drainage or slope stability issues must be addressed in an Erosion and Sediment Control Plan.

Recreation Impacts

Recreation is an important resource which tends to become more important with the passage of time. Development of a project with provision of road access may induce recreation in the project area. Recreation use may increase with time or change with trends in recreation.

It is also important to stay abreast of any existing or proposed designated wilderness areas in the project area, and any river segments included in, or designated for, study under the Wild and Scenic Rivers Act. This may preclude any change to an existing project.

The interaction between any modifications in the plant and recreation opportunities needs to be carefully considered as part of the process of planning a modernization project. Proposed changes in plant operation or ramping rates may impact downstream recreational use of the river. Changes in reservoir water levels may have impacts on recreation use of a reservoir. Extensive modernization of the plant may precipitate the need to upgrade or expand recreation facilities, so these costs should be factored in to the modernization plan including any additional future operating and maintenance costs. Any tangible recreation benefits in the form of user fees or alike may offset additional costs, however, in many cases recreational facility benefits are intangible public benefits which do not accrue revenue to the applicant.

As part of a new licence application, re-licensing application or capacity-related amendment the owner is required to prepare and submit a recreation plan documenting existing and projected recreation use and proposed facilities to be provided to address recreation impacts.

Historical and Cultural Resources

Many hydro projects are historic landmarks. Historical and cultural resource considerations bear special attention in these cases as they may complicate the process of modernizing a plant.

In some instances it may be expedient to duplicate an existing plant rather than to attempt to upgrade it or modernize it within many constraints due to the plant’s significance as a historical landmark. In other cases where replacement is not a viable option, historical and cultural resource factors may limit the types of modernization or upgrading measures that are feasible.

Construction Impacts

Impacts of construction activities also need to be addressed. An erosion and sediment control plan is usually required where ground-disturbing activities are planned and a hazardous materials plan is required where such materials are involved. Be wary for any hazardous or toxic material

such as old transformer oil that may be stored, dumped or even used in the past for dust-control around a plant. Asbestos is another troublesome material that may occur in old plants as insulation or as asbestos-cement siding on buildings.

Painting or coating systems used as part of modernization projects should be carefully considered in terms of potential environmental impacts. For example creosote that used to be used as a wood preservative on pilings, wooded tanks and some woodstave penstocks is not used much today because of its toxic nature. In cases where shotblasting or sandblasting of old coatings and corrosion products is anticipated a plan should be developed for containing and disposing of stripped material and spent sand.

Special operation plans that may require a change in reservoir operation to facilitate construction work may be needed. Any change that effects use of the reservoir as fish or wildlife habitat or for recreation will require consultation with resource agencies and other stakeholders. Modifications to downstream flow releases may also be required to facilitate construction—this also needs to be addressed through consultation.

One complication in dealing with construction impacts is that at the time the permitting is carried out the contractor will not have been selected. In most cases it is best to hand over to the contractor (as much as possible) the day-to-day responsibility for meeting environmental requirements. However, the contractor should also be given the ability to choose construction techniques best suited for the project including meeting the environmental requirements. The best approach is to keep the project planning and permitting at the conceptual level and provide the contractor the maximum flexibility to modify or refine construction processes to meet construction and environmental quality goals.

Access

Access should be carefully considered when planning to modernize a project. In terms of terrestrial impacts, road access for new construction may pose some new problems which have not been issues with maintaining the project.

Access becomes especially important on projects located on Forest Service lands or within wilderness areas or where land ownership and use has changed substantially since the project was first constructed. Construction traffic impacts on road use may be an issue on larger modernization projects in sensitive areas, but for most small modernization projects this is not an issue.

Reopeners

Licence re-openers are open-ended licence conditions that may be reevaluated and changed during the licence period. In dealing with these types of issues the project owner has to balance the risks of future changes against the feasibility of agreeing to a price that may be paid for certainty.

6.5 Screening and Ranking Candidates

Purpose of this Section

The purpose of this section of the manual is to provide the reader with a simple way of categorizing candidate plants relative to institutional and regulatory issues.

The ***screening process*** is designed to determine those plants that are not suitable for life extension or modernization and should not be considered further.

The ***ranking process*** is designed to prioritize the candidate plants that survive the screening process so that resources can be allocated in a timely way to the most promising candidates.

Screening Process

Some I/R issues may render projects unsuitable for life extension or modernization as follows:

- ***Mandatory decommissioning*** - Some projects that are located in environmentally sensitive areas such as on anadromous fish runs, or within Wilderness Areas or National Parks may be subject to mandatory decommissioning. Recent examples are Edwards Dam and the Elwha Dams in the U.S.
- ***Potential Federal Government takeover*** - This happens very infrequently however, some projects may become subject to takeover by the Federal Government. An example is the Melones Project in California where Pacific Gas and Electric Company's 49 year old Melones Powerplant was condemned in 1976 to allow construction of the Federal Government's New Melones multi-purpose water supply/flood control reservoir and 150 MW hydro plant.
- ***Forced or Portfolio Divestiture*** - With the advent of utility restructuring many utilities are being required to divest all or part of their generation assets. These requirements vary from state to state and either may or may not affect hydro generation assets. Many utilities that are required to divest all or part of their fossil assets are deciding to divest their hydro assets as part of the portfolio in an overall decision to exit the generation sector.
- ***Grossly uncompetitive in market*** - Some existing hydro plants are grossly uncompetitive under market conditions and are obvious candidates for either divestiture or decommissioning. Typical candidates in this category are small remote run-of-river plants with high maintenance impoundments or water conveyance structures, or low generation plant factor.
- ***Redevelopment projects*** - If redevelopment of the project is envisaged to meet other water resources or public interest objectives then life extension or modernization would probably not be pursued.

Ranking Potential Candidates

Projects in a portfolio that pass this gross screening can be ranked to determine priorities for planning and implementation (see Section 3).

There are two main issues here: timing and constraints. In some cases, terms or expiry dates of existing permits and licences may be drivers that define a timeline for planning and permitting of activities. In other cases limiting institutional/regulatory constraints may downgrade the feasibility of modernization opportunities at a candidate plant relative to other plants which may be important when prioritizing projects.

This step requires that the owner is familiar with the regulatory classification and expiry date of permits, licence and agreements for each project. For each project the licensing classification, date of expiry of the existing licence, and known limiting constraints are tabulated. Separate rankings are given for timing issues and for limiting constraints. An overall subjective ranking can be made by a subjective combination of the individual rankings. A typical example is shown on the following box:

LICENSING DATA						TIMING				LIMITING CONSTRAINTS					RANKING
Project	Installed	FERC	License	Expiry	Remaining	Critical	Imminent	Flexible	Ranking	T&E	Historic	Fish	Recreation	Ranking	
Name	Capacity	Number	Classification	Date	Life	0-5	6-10	>10		Species	Preservation	Passage	Impacts		
	(MW)				(years)										
Able	50	9998	License	04/30/06	7		x		2	x	x	x		3	3
Baker	75	9997	License	9/30/15	16			x	3				x	1	2
Charlie	4	9287	Exemption	none				x	4		x			1	4
Dingo	20	8979	License	3/31/02	3	x			1				x	1	1

6.6 Developing a Licensing Plan

Introduction

There are several steps in developing a licensing plan for a modernization project. These are as follows:

- Setting Goals
- Identifying participants
- Identifying issues, constraints, risks and opportunities
- Determine Licensing Category
- Considering Licensing Options
- Decision-making
- Action Plan

Goals

Setting goals is the first and most important step as it lays the foundation for the plan, decision-making and any course of action that follows.

Before embarking on a modernization project and making many decisions it is important to be clear as to what the goals of the endeavor are. Goals of various hydro plant owners vary but may fall into several general categories as follows:

- Financial Success
- Security
- Growth
- Manage risks
- Excellence in service
- Quality of experience
- Resource stewardship
- Citizenship
- Public Relations

It is important to write goals down and modify them, if necessary, as needs change.

It is also important to consider what the goals or interests of other participants in the process may be, however, these goals should be viewed as separate objectives, which may or may not become project goals.

Participants

The licensing process is more and more becoming a consensus-driven people process. The first step in the process is to identify all stakeholders involved so that they can be made aware of the proposed action and choose to participate or not in the licensing process. The best way is to create a database of names, addresses and interests in one of the many contact management computer programs available and use this program to document the record of contact with stakeholders and interested parties. Documentation is important both for licence application purposes and for tracking communications which may involve many people over many years.

To identify the parties involved you can review previous correspondence in the project files to determine interested parties. For many existing projects most of the resource agencies and stakeholders involved will be a matter of record. FERC staff and resource agency staff can also be helpful in identifying potentially affected or interested parties. The key is to identify all parties and then edit down the list to those who are affected or who choose to participate.

Many stakeholders may choose not to participate after determining that their interests are not affected by the project. They may attend one meeting and then be happy to just stay on the mailing list. However, late entrants into the licensing process can be a problem for the applicant and can undo many months of communication and consensus-building.

Most consensus-building process involve a process of discovery of issues, communication of needs, learning, developing personal relationships, attitude adjustment, problem solving and negotiation. The participants essentially embark on a journey together that hopefully leads to a consensus on some or all of the issues at stake. Latecomers to the process may derail it because they feel that their needs have not been addressed in the consensus process.

The process of communicating with, facilitating meetings with and disseminating information to interested parties should not be underestimated. The applicant needs to decide to what degree it wants to sponsor and lead the process or share this responsibility with other participants.

Issues

Early understanding of project issues can help with planning and decision-making. A generic discussion of various potential licensing issues is presented in Section 6.4.

First of all it is good to inventory all the significant issues i.e. constraints that affect the project. Next the significant issues or constraints are divided into risks (negative outcome) and opportunities (positive outcome). This process helps to screen out infeasible alternatives and in identifying those actions that have a good chance of gaining regulatory approval. By looking carefully at opportunities the owner may also identify win-win approaches to resolving issues and meeting goals.

Constraints

Constraints are significant issues that affect the planning and implementation of a project. Some constraints may be potentially fatal which means that any conflict with the constraint will render that action unfeasible. Other constraints may be negotiable which means that some flexibility exists and mitigation measures are acceptable.

Fatal

Potentially fatal constraints are as follows:

- Impact on endangered species
- Wild and Scenic River Designation
- Impact on national park or wilderness area
- Impact on anadromous fish migration
- Water rights conflicts

Negotiable

- Impact on resident fish habitat mitigated through in-stream flow releases, fish hatcheries or direct improvements to fish habitat.
- Recreation mitigated through in-stream flow releases or providing recreation facilities.
- Terrestrial impacts mitigated through on-site or off-site habitat improvement.
- Agreements.

Risks

Some typical risks are as follows:

- Reopening existing closed issues
- Changing the balance of water use
- Complying with new plans or regulations
- Disclosing proprietary information
- Water rights issues

Opportunities

Some typical opportunities are:

- Resolving existing conflicts.
- Gaining operating flexibility.
- Trade-offs.
- Implementing new approaches to environmental protection or mitigation that both benefit the resources and the project.
- Resolving uncertainty.

Determine your Licensing Category

Licensing requirements differ depending on the category of project. From a licensing standpoint modernization projects fall into one of three main FERC licensing categories as follows:

- No FERC Jurisdiction
- Licence
- Exemption

Under each of the latter two categories there are a number of sub-categories that are discussed in the following sections:

No FERC Jurisdiction?

Projects in this category include:

- Federal projects.
- Projects on privately owned lands that do not affect a navigable waterway or interstate commerce (e.g. a project on a small unnavigable stream on private land that is not connected to an interstate utility grid some small remote projects and projects in Alaska and Hawaii meet these criteria).
- Projects that are exempt by statute.

If the owner determines that the project does not fall under FERC jurisdiction then the approvals needed for any modernization will be determined by State, county and local regulatory requirements and possible jurisdiction under other federal statutes including:

- Clean Water Act
- Coastal Zone Management Act
- Endangered Species Act
- Fish and Wildlife Coordination Act
- National Historic Preservation Act
- Wild and Scenic Rivers Act

In most cases the types of approvals needed may include water rights, approval under state environmental quality regulations, fish and game permits and construction permits.

Licence

There are four sub-categories within this classification:

- No action
- Capacity-related Amendment
- Non-Capacity-related Amendment
- Re-licence

No Action

No action is required if the modernization project is consistent with the existing project authorization. The starting point is to carefully review the licence issued by FERC and determined whether the proposed modernization is consistent with this authorization. Pay special attention to the project description and any licence articles that limit the scope or operation of the plant.

If the licence document needs to be changed to address proposed changes in the design or operation of the project then an amendment is probably required. If there is any doubt, then FERC staff can be contacted to get their assistance in making this determination.

Capacity-related Amendment

A capacity-related licence amendment is required for modernization projects that involve additional capacity not previously authorized and would result in an increase of the installed nameplate capacity of 2 MW or more, and result in increase in the maximum hydraulic capacity of the project of 15% or more.

The licensing process for this type of amendment is modeled after the process of applying for a new licence so applicants need to carefully consider the time and cost involved in gaining regulatory approvals.

One advantage of an amendment versus a new licence is that the licensing process is more narrowly focused on issues related to the proposed project modification. A disadvantage is that the approval is only for the duration of the original licence, which in some cases may make the modernization project economically infeasible.

Alternative processes such as the APEA process can be utilized where appropriate.

Non-capacity-related Amendment

All amendments that do not meet the criteria for capacity-related amendments are non-capacity amendments. The application requirements for this type of amendment vary with the nature of the changes proposed.

To define the scope of the application the licencee should contact FERC, describe the nature of the proposed amendment, and get direction regarding any consultation required with resource agencies and appropriate exhibits to include in the application. In most cases the application takes the form of a letter that describes the purpose and scope of the amendment, includes copies of relevant correspondence with resource agencies, and provides updated exhibits including drawings and maps.

Re-licence

Re-licensing can either be an incentive or disincentive to modernization depending on how much time is left in the existing licence.

- ***New Licence (25 or more years to expiry)***—Re-licensing is not an issue, a licence amendment is probably the best course.
- ***Mid term (10 to 25 years to expiry)***—In cases where the licence has between 10 and 25 years left until expiry a couple of factors need to be considered:
  - Is there enough time to recover the capital invested in modernization?
  - Is competition for a new licence likely?
  - Is it worth bringing forward re-licensing to get another 30 year licence term?
- ***End of Term (5 to 10 years to expiry)*** - Re-licensing provides an opportunity to incorporate modernization into a new licence. The advantage is that it can be incorporated into the re-licensing process thereby avoiding a separate proceeding. The disadvantage is that it may raise new issues which may adversely affect the remainder of the project. This has to be determined on a case-by-case basis.

Special consideration needs to be given to small projects just less than either 1.5 MW or 5 MW in capacity. A small increase in capacity may change the licensing category of projects just under these thresholds, which may trigger the need for additional information and new licence terms and conditions.

Exemption

No Action

No action is required if the modernization project would not violate existing terms and conditions imposed by Federal and State fish and wildlife agencies and would not materially alter the design, location, and method of construction or operation of the project.

The starting point is to carefully review the terms and conditions in the exemption order and determine whether the proposed modernization project is consistent with this authorization and existing terms and conditions.

If there is any doubt, Federal and State fish and wildlife agencies should be notified of proposed changes in the project and FERC staff should be contacted to determine whether the modernization project involves material changes to the authorized project. If either determination is affirmative then the owner must apply for an amendment of the exemption.

Amendment

If the modified project still qualifies for an exemption, then an amendment application must be filed. To complete the amendment application, the exemptee must revise relevant exhibits that are representative of the proposed project. The exemptee should consult with FERC staff to determine which exhibits should be revised for submittal with the amendment application.

Reclassification

Special consideration needs to be given to privately held small projects just less than either 5 MW capacity in the case of a small hydro project or 15 MW in capacity in the case of a conduit plant. For publicly owned conduit projects the threshold is 40 MW.

A small increase in capacity may change the licensing category of these projects such that they are no-longer eligible for an exemption and trigger an application for a new licence. The cost, time and regulatory risk involved in licensing an exempt plant would have to be weighed against the benefits of modifying the plant.

Consider Licensing Options

FERC can approve modernization projects by amending the project's existing hydropower licence/exemption, by issuing a new licence for the modernized project, or by issuing an exemption for the project.

Each of these options has advantages and disadvantages described below.

Licence Amendment

The principal advantages of amending the existing licence are that:

- FERC does not allow any competing applications to be filed in an amendment proceeding. Consequently, the owner does not risk losing the project to another entity with a better modernization or redevelopment plan.
- The amendment process is limited in scope to the proposed change and matters directly relating to the anticipated project changes. Consequently, the scope of the relevant issues in the amendment proceedings is narrower than in re-licensing proceedings.

However, the principal disadvantage of amending the existing licence is that FERC rarely extends the remaining term of the licence. For modernization of older projects whose existing licence will expire in less than 20 years, renewal of the existing licence may be necessary for modernization to be financially attractive. If the owner proceeds with the modernization without obtaining an extension of the existing licence, the owner may risk financial losses resulting from not obtaining a new licence for the modernized site when the existing licence expires.

New Licence

Obtaining a new licence for the modernized project provides a longer period to recover invested capital and lower uncertainty about future changes since the term of the new licence issued by the FERC will be at least 30 years depending on the extent of the proposed redevelopment.

A disadvantage to re-licensing the project is that competing applications may be filed in a re-licensing proceeding. However, existing licencees rarely lose projects to competing applicants if they can have a satisfactory compliance record and can show sound plans for maximizing beneficial use of the resource within environmental constraints.

In the event that either the government takes over the project or awards the new licence to a competing licencee, then the existing licencee receives compensation equal to its net investment in the facility (not to exceed fair market value) plus severance damages. The criteria for determining compensation is more fully described in Sections 14.0 and 15.0 of the Federal Power Act.

Another disadvantage to re-licensing the modernization project is the extended scope of the issues considered in the re-licensing proceeding. The re-licensing proceeding is required to address the entire project, not just those aspects, which will change. Consequently, issues relating to the original condition of the project waters and environment may be raised. For some sites, particularly those involving anadromous fish passage, this may be a serious problem because of the additional significant costs. However, the owner should consider that these issues will have to be addressed eventually when the project is re-licensed.

The Federal Power Act requires that the existing licencee inform FERC of its intentions concerning re-licensing at least 5 years before the licence expires. The existing licencee must also make available to the public sufficient information so that a potential competitor can evaluate the hydropower potential of the site and prepare a competing licence application. FERC will accept re-licensing applications from any party until 2 years prior to expiration of the existing licence. (The combination of the 5 year and 2 year deadlines is to create a 3 year “open competition” period.)

For those projects which involve extensive redevelopment and which have more than 5 years remaining on the existing licence, it appears likely that FERC will not seriously process any re-licensing application until the three-year open competition period has passed. FERC may achieve this objective by agreeing to terminate an existing licence 5 years after receipt of a petition requesting such an action, coupled with proof the existing licencee has met the public information requirement as well. FERC would then accept re-licensing applications for the site only for the next 3 years.

Licence Exemption

The principal advantage of obtaining an exemption from FERC is the shorter time required for FERC to issue it. The owner of an exempted project also does not have to pay FERC any annual fees based on use of federal lands or annual generation.

However, the principal disadvantages of the exemption process are the qualification limitations the exempted project capacity is limited to 5 MW, and the project must either use an existing non-federal dam or meet the criteria of a "natural water feature" project.

Another substantial disadvantage of an exemption process is that it does not preempt the need to obtain most other federal and all state/local permits for the project. An exemption also does not convey the right of federal eminent domain[22] for the owner to secure rights to the project site and transmission line corridor.

Traditional or Alternative Process

For modernization projects that require a non-capacity-related amendment licensing is mainly an administrative matter handled according to FERC's regulations and procedures with assistance from FERC staff in scoping the required application.

In the case of a non-controversial capacity-related amendment that does not involve significant environmental issues the traditional process is often best as it confines the process to the proposed change and avoids initiating a more wide ranging consensus process bringing in other issues and needs.

In the case of a capacity-related amendment or re-licensing in which there are significant environmental issues and the need for an environmental review, the owner should give consideration to using an alternative collaborative process to avoid the potential delays, uncertainties and costs of the traditional FERC process.

Decision-making

Good decision-making is the result of good information, careful consideration of all significant factors including uncertainties and of course an element of chance or luck.

Experience is often an important aid in decision-making. In many cases the lessons learned in previous similar circumstances can be successfully applied. In some cases, risks can be handled by adopting a plan that has flexibility built in to address uncertainty.

As decision-making has become more complex it has developed into a science. There are many tools now available to support decision makers in evaluating and ranking options. These tools help achieve consensus. They also document the basis for a decision in case that needs to be revisited at some later time.

Action Plan

The action plan is the outcome of the planning process. It defines a planned course of action and provides the path for reaching the goals identified early in the process.

[22] The right to condemn property rights to gain ownership or access.

Action plans may vary from a simple memo listing a series of actions and completion dates, to a more detailed "business plan" that presents the goals, selected approach, a work plan comprised of a series of discrete tasks, schedule, resource plan and budget. Action plans may also address risks through contingency plans or "off-ramps" which become active if certain events take place.

6.7 Glossary of Licensing Terms

The following is a glossary of selected licensing terms used in this section.

ADEQUATE - a determination by the FERC that a licence application conforms to the requirements for the particular project type as specified in 18 CFR Parts 4 and 16.

AMENDMENT - make a change in the physical features of the project or its boundary, or make an addition, betterment, abandonment, or conversion, of such character as to constitute an alteration of the licence.

COMPREHENSIVE PLAN - those comprehensive plans referenced in Section 10.0(a)(2)(A) of the Federal Power Act, as defined by FERC regulations (18 CFR 2.19).

CUMULATIVE IMPACTS - the effect on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time.

DAM - structure for impounding water.

DEFICIENT - a determination by the Director, OHL that a licence application does not fully conform to the requirements for the particular project type as specified in 18 CFR Parts 4 and 16. An applicant having a deficient application is afforded additional time to correct the deficiencies.

DISMISSAL - the termination of licence application processing resulting from a determination b FERC that an applicant has failed to provide timely additional information or documents that the Commission requires as being relevant for an informal decision.:

EA - environmental assessment

ECPA - Electric Consumers Protection Act

EIS - environmental impact statement

ENHANCEMENT - the act of increasing the value or effectiveness of a resource beyond the level that exists at the time of the application.

FERC - Federal Energy Regulatory Commission

FPA - Federal Power Act.

INDIAN TRIBE - in reference to a proposal to apply for a licence or exemption for a hydropower project, an Indian tribe means a separate and distinct community or body of people of the same or similar aboriginal race historically inhabiting areas within the United States that:

- is united in a community under one leadership or government constituted by law or long-standing custom;
- inhabits a particular territory;
- is recognized by treaty with the United States, by federal statute, or by U.S. Secretary of the Interior; and
- whose legal rights a tribe may be affected by the development and operation of the hydropower project proposed, as where the operation of the project could interfere with the management and harvest of anadromous fish or where the project works would be located within the tribe's reservation.

LICENCE - FERC order authorizing construction and operation of a hydroelectric project.

MAJOR MODIFIED PROJECT - any major project that would include:

- any repair, modification, or recommendation that would result in a significant change in the normal maximum surface area or the normal maximum surface elevation of an existing impoundment, or
- any change in existing project works or operations that would result in a significant environmental impact.

MAJOR PROJECT - EXISTING DAM - means a licensed or unlicensed, existing or proposed waterpower project that would:

- have a total installed generating capacity of more than 2000 hp (1.5 MW)
- not use the waterpower potential provided by any dam except an existing dam.

MAJOR PROJECT – 5 MW OR LESS - Any major project/existing dam, or any major unconstructed project that has a total installed capacity of 5 MW or less.

MITIGATION - the act of making a potential impact from a major modification, new project, or non-power project less severe.

Mitigation includes but is not limited to:

- avoiding the impact altogether by not taking a certain action or parts of an action;
- minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
- compensating for the impact by replacing or providing substitute resources or environments.

NEW LICENCE - a licence for a waterpower project issued under Section 15.0(a) of the Federal Power Act after an original licence expires (excluding annual licences).

NEPA - National Environmental Policy Act.

NON-POWER LICENCE - a licence for a project that does not include power generation as a project purpose.

NOPR - Notice of proposed rule making.

OHL - Office of Hydropower Licensing.

ORIGINAL LICENCE - the first licence issued for waterpower project under either the Federal Water Power Act of 1920 or the Federal Power Act.

PATENTLY DEFICIENT - a determination by the Director, OHL, that a licence application substantially fails to comply with the requirements specified in 18 CFR Parts 4 and 16, or that the application is for a project that is precluded by law. An application determined by the FERC to be patently deficient is rejected.

PROJECT - complete unit of improvement or development, consisting of a powerhouse, all water conduits, all dams and pertinent works and structures including navigation structures which are part of said unit, and all storage, diverting, or forebay reservoirs directly connected therewith, the primary line or lines transmitting power therefrom to the point of junction with a distribution system or the interconnected primary transmission system, or miscellaneous structures used and useful in connection with said unit or any part thereof, and all water rights, rights-of-way, ditches, dams, reservoirs, lands, or interest in the lands the use and occupancy of which are necessary or appropriate in the maintenance and operation of such unit.

REJECTION - the response of the FERC to a licence application determined by the Commission to be patently deficient. An application that is rejected may be resubmitted, but the date the rejected application is resubmitted is considered the filing date.

RESOURCE AGENCY - a federal, state or interstate agency exercising administration over the areas of flood control, navigation, irrigation, recreation, fish and wildlife, water resource management (including water rights), or cultural or other relevant resources of the state or states in which are project is or will be located.

SMALL HYDROELECTRIC PROJECT - any project in which capacity will be installed or increased after the date of notice of exemption or application, which will have a total installed capacity of not more than 5 MW and which meets the specific criteria of 18 CFR 4.30(b)(27).

SUBSEQUENT LICENCE - a licence for a water power project issued under Part I of the Federal Power Act after expiration of a minor or minor part licence not subject to Sections 14.0 and 15.0.

7
FEASIBILITY

Modernization Plans provide an overview level evaluation of the alternatives being considered. The equipment data and costs used from Volumes 2 to 7 provide input to the initial assessment of the plant modernization potential. If modernization potential is identified and the plant is prioritized for investment by the utility (refer to Section 5) then, a detailed, in-depth Feasibility Study may be warranted depending upon the importance, complexity and cost of the proposed works. The purpose of a Feasibility Study is to confirm the modernization plausibility, i.e. that the work is possible and makes economic sense, and refine the modernization plan through more in-depth equipment selections along with more accurate cost, capacity, generation and other benefit estimates. The cost estimates will be brought to a level required for project approval.

In general, life extension requirements have already been determined, and while some further analysis or testing may be required, it is unlikely to be excessive. Feasibility will help improve some of the economic numbers for any prioritization process.

The Feasibility process is similar to that used to develop a Life Extension and Modernization Plan in Section 4, though conducted in more detail and depth. The process is set out in Figure 7-1. A sequence of activities through feasibility, project definition and implementation activities is set out in Table 7-1.

Volumes 2 to 7 will provide both technical information on specific equipment for optimization and feasibility design, and guidance on estimating costs and benefits to the appropriate level.

The tables in Section 4 were the basis for identifying modernization opportunities. At feasibility level, more detailed information will be required to refine the assessments and allow more accurate estimates of costs and benefits. The level of accuracy for cost estimates during feasibility will be improved from the ±20 to 35% range in Section 4.0 to ±17.5 to 25% here in Section 7.

Additional testing, both on and off site, may be required to supply more accurate assessments for both the assessment of plant condition and the analysis of needs and requirements.

During Feasibility, a milestone schedule will be developed defining the steps, activities, and time requirements for the implementation process. Where possible, the modernization work and plant shutdown are scheduled to minimize lost generation during periods of low water availability or a low selling price of electricity. The milestone schedule can also be used during implementation to monitor the progress of the work being performed.

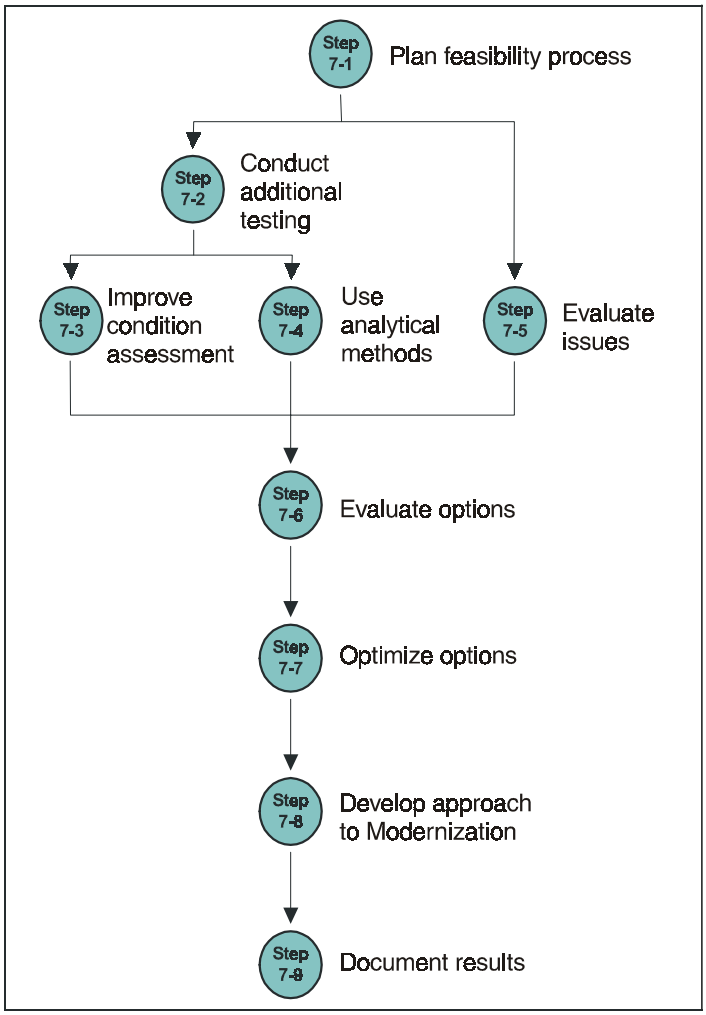
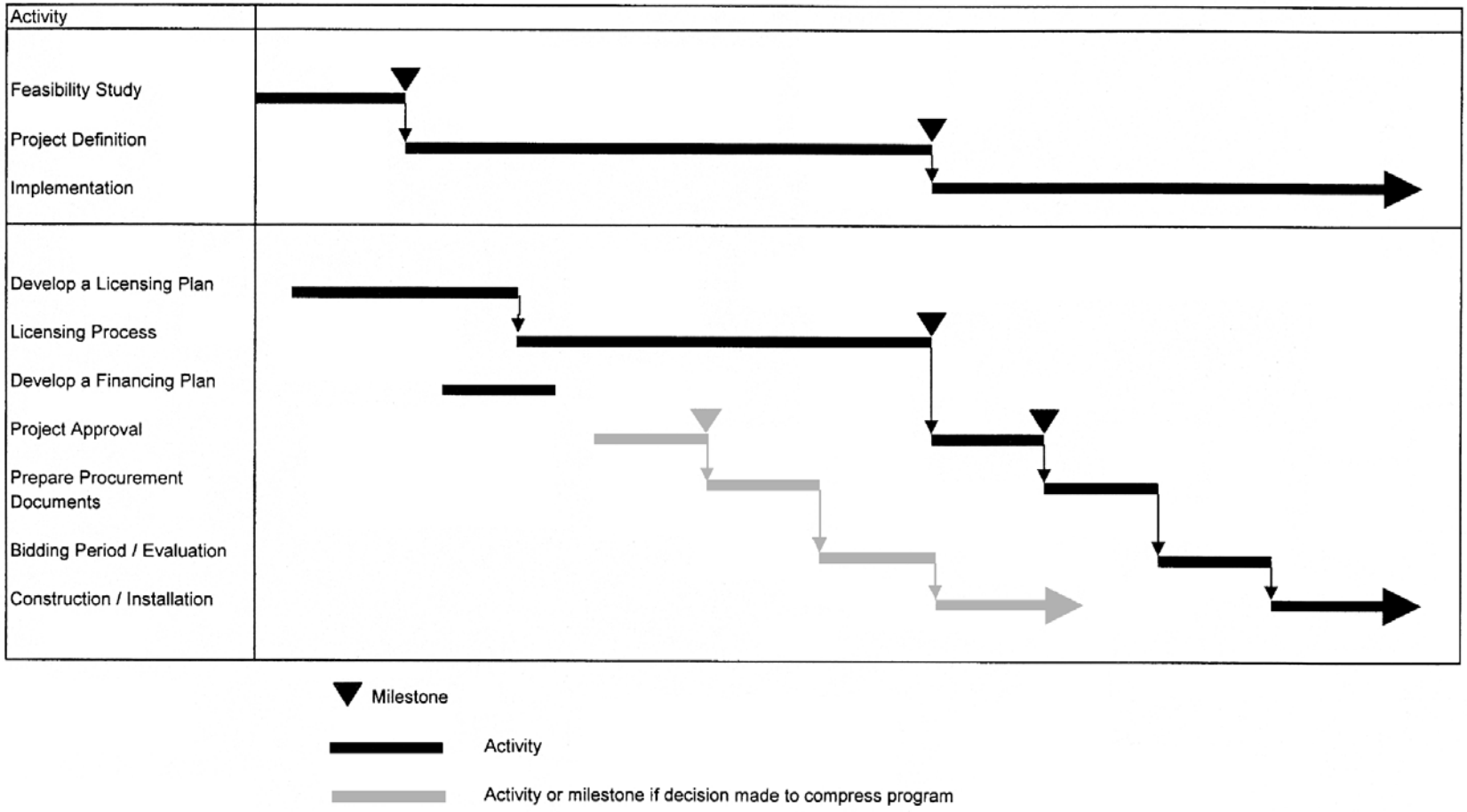


Figure 7-1
Feasibility

Table 7-1
Sequence of Feasibility, Project Definition and Implementation Activities



7.1 Plan Feasibility Process

Modernization Plans outline opportunities for the particular plant, in the form of discrete activities or projects. These are now assessed for their feasibility.

The planning of the feasibility process, Step 7-1, addresses:

- Which opportunities/activities/projects will be taken from the Life Extension and Modernization Plan to feasibility?
- What needs to be done to prove the feasibility of the activities?
- How will the selected approach to modernization be developed?

The Life Extension and Modernization Plan (the Plan) formulated in Section 4 is reviewed to determine which opportunities are appropriate for moving through feasibility towards probable implementation. This will align with the priorities set out for the utility's portfolio in Section 5. Information from Technical Volumes 2 to 7 is also collected for use in the feasibility studies.

Sometimes, there will be more than one way to realize the opportunity available. Alternatives are identified and also evaluated for feasibility. For example, an uprating of a generator may be realized by modernizing the equipment or by simply operating the unit closer to its design limits (and above its nameplate capacity). The decision on which way to achieve the uprate will depend on the remaining life of the generator, the expected effect on the equipment of this over-rating and what other modernization works are feasible.

Proving the feasibility of the activities/projects requires the following:

- Additional testing to obtain an extra level of detail.
- Improving the assessment of plant condition which will refine the Base Case for Life Extension, together with an estimate of costs and benefits.
- Refining Modernization options and estimating costs and benefits incremental to the Base Case.
  - Evaluating non-technical issues to a greater level of detail.
  - Optimizing the options considered, and selecting the most attractive.
  - Estimating all costs and benefits of selected option to a greater level of detail.

The level of detail required for these activities can be estimated. However, as the process continues, additional requirements may present themselves as a result of information uncovered.

The resources used to undertake the feasibility analysis may come from a number of sources. This is discussed in Section 2.1.5 and includes the following:

- Internal resources only
- Internal resources with consultants assisting for portions of the work
- Consultant resources with an internal project manager

- Manufacturers
- A combination of the above

Some hydro plant owners have entered into agreements with manufacturers that covers a number of plants, for a specific period and specific equipment. The most common is for turbine runner replacements. However, even in this case, the manufacturer's input, though important, would generally only form a part of the overall feasibility process.

For all feasibility activities, a clear understanding of the objectives of the work, the scope of work and costs and timing are required. A project management system with assigned tasks and responsibilities set out in a Project Plan is recommended. A Quality Plan is also strongly advised.

7.2 Additional Testing

Additional testing, at this stage, can include on site and off site testing. The results of the testing will provide either:

- input to the improved assessment of condition to allow a better definition of remaining life and what needs to be done to extend it; or
- input to the analytical methods to help assess opportunities for improvement.

Testing is expensive both in real costs and the time the unit is out of service. The basis for conducting a particular test will require justification prior to its commencement.

The REMR[23] manual identifies many tests that are used to assess plant condition (Step 7-3). Tests which have been found useful are listed in Table 7-2. More information on these tests is provided in Volumes 2 to 7.

[23] Repair, Evaluation, Maintenance and Rehabilitation Research Program, developed by the U.S. Army Corps of Engineers. (REMR Home Page www.wes.army.mil/REMR/remr.html).

Table 7-2
Examples of Additional Tests

Generator Tests

Stator
- Blackout
- Corona Probe
- DC High Pot
- Insulation Resistance
- Ozone Detection
- Partial Discharge Analysis

Rotor
- Pole Drop
- Insulation Resistance
- Polarization

Thrust Bearing
- Oil Condition

Turbine Tests
- Efficiency
- Flow

Governor Tests
- On-line Performance
- Off-line Performance

Gate Tests
- Performance

Cranes
- Performance
- Crack

Transformer Tests
- Dissolved Gas Analysis
- Furan Analysis
- Oil Quality Analysis

Oil Circuit Breaker Tests
- Oil Condition
- Doble
- Response Time

An example of the cost implications of testing is the use of turbine runner hydraulic model testing. Laboratory model testing of turbine runners is normally conducted during the Project Definition or Implementation phases of a project. As an alternative, CFD analysis may be used during Feasibility, if the potential benefits justify the costs. Details regarding model testing and CFD are included in Volume 2.

Example

Insulation resistance for the No. 1 Unit generator is tested using partial discharge analysis. The results reveal that the remaining life assessment that originally stood at approximately 8 years in Section 4.0 is inaccurate. In fact the remaining life is now assessed at 5 years which may change the options under consideration.

The original estimate was based on site records, discussions with site staff and the results of insulation resistance testing from 5 years ago. Following partial discharge analysis it is apparent that the insulation degradation is accelerating.

Example

Model testing of a proposed upgraded turbine runner for No. 1 Unit is undertaken in the laboratory. The results of the testing reveal that the upgraded runner can offer efficiency improvements averaging 5% over the existing runner. Previous figures used in Section 4, during the formulation of the various modernization options, estimated an average efficiency increase of 4% using estimates from previous upgrade experience and from manufacturers.

Cavitation concerns, which caused annual outages for repairs to the existing runner, may also be significantly reduced with the installation of the upgraded runner.

These benefits can now be quantified using power study analyses and included as inputs to the financial model in later steps.

7.3 Improved Assessment of Condition

The Plant Survey process in Section 4 included an overview level condition assessment. During the feasibility study a more comprehensive assessment of condition will be required for equipment that is critical to the Plan. One of the prime purposes will be to better define the remaining life of specific equipment. This allows decisions to be made on replacement, prior to failure, and assessment of modernization options as incremental improvements over life extension.

The condition assessment at feasibility level uses the same procedure as that outlined in Step 4-3 but the difference is the increase in the level of detail and some of the assessment parameters obtained. The additional detail may be gained by means of additional testing of plant, such as efficiency tests or partial discharge testing, or by inspections of plant items which were not undertaken during the initial site inspection conducted in Step 4-2. The level of inspection may require the plant to be out of service and also operated under test conditions. The assessment team used will be larger and staffed with experts rather than the generalists used in Step 4-3. The experts, however, will only focus on specific pieces of equipment rather than the whole plant.

REMR contains a standardized process to assess the condition of equipment based on the results of various tests. From these a Condition Index is assigned. REMR covers some of the key equipment types, however, many others are not included. Extrapolation of the methods discussed in Section 4 can be used for these.

It has to be remembered that in an ageing, but still operating, hydro plant, the condition of the assets can generally not be accurately assessed. The application of new technology can inadvertently raise risk exposure. Therefore those risks must be carefully considered in the design phase.

Volumes 2 to 7 contain technical information required for condition assessments of specific equipment.

Example

The turbine runner for the No. 1 Unit of the plant was assessed to be in need of replacement. Cracks have been noted and cavitation repairs are needed annually requiring an expensive outage.

Condition assessment used historic records of costs of repairs and outages. Remaining life was assessed based on this activity as well as evaluating the risks of losing a blade and consequent damage.

The option of a replacement runner will be assessed based on:

- improvements in efficiency and power output
- reductions in cost from reduced maintenance work and outage time

The option will be assessed on as incremental improvement based on the remaining life of the existing runner.

7.4 Use Analytical Methods

Analytical methods will help improve the knowledge base concerning the modernization options that are being considered. This increased knowledge base will better define the costs and benefits of the modernization options.

Examples of analytical methods include:

- Power Studies
- Turbine modelling by numerical methods
- Buildability analysis
- Value Engineering

The decision on the type and extent of analysis undertaken is usually based on its cost-effectiveness. Turbine runner modelling is either done by laboratory model during Project Definition and Implementation, or by numerical methods such as Computational Fluid Dynamics (CFD). Both are expensive and the choice and whether to proceed is based on the expected benefits to be gained.

Power Studies

Power studies are used to improve the level of accuracy and ensure the effective use of the water resource. The base case scenario and the alternatives being investigated can be used in the study with each scenario checked to ensure its validity against the power study data. Average annual or monthly outputs can be estimated along with monthly output duration curves. More sophisticated models can provide daily and hourly results.

At feasibility, energy estimates are conducted with greater sophistication and accuracy. Headwater fluctuations, hydraulic losses, tailwater rating curves, and actual unit(s) performance are modelled for the generation analysis using actual monthly or daily flow data for a selected period of record. The extent of data used in the power study will be broadened from that used in Section 4.0. For example, 5 years of data on an annual basis may have been used in Section 4.0 whereas 40 years of data on a monthly or daily basis may be used at this stage.

Details of power study procedures are found in Volume 6.

Turbine Modelling by Numerical Methods

CFD can be used to model the expected performance of an upgraded turbine runner and the hydraulic performance of an upgraded turbine as a whole. Volume 2 provides details for additional information.

Buildability

Buildability refers to the ability of the project proposed to be constructed within the physical constraints identified. This is particularly important in the case of life extension or modernization as both are retrofitting processes with additional constraints that do not exist with a greenfield site. Areas of concern include:

- Transport access to site, especially as conditions for access may have changed since initial construction.
- Space constraints inside the powerhouse for the installation of new equipment or working on existing equipment or clashes of both activities.
- Capacity of existing equipment such as cranes to handle the project requirements.
- Availability of services for increased activity on the site.
- Interference with other planned activities on the site.

Powerhouse and equipment arrangement sketches which are prepared at this stage for the equipment layout and for use in the subsequent purchase of equipment will be used to conduct the analysis of on-site components.

A buildability assessment may also allow innovative construction methods to be identified for the project which will reduce direct costs or outage times.

Assessments of the civil structures may also be performed to confirm the project features' ability to economically support plant operation over the entire modernization period. The existing structural design should be assessed relative to the present FERC design and other regulatory requirements, since such requirements might be imposed during relicensing.

Industrial relations concerns may also need to be addressed briefly at this point to determine if any labour issues will be expected to occur during implementation, e.g. union and non-union labour on site. Any costs associated will have to be factored in.

Value Engineering

Value Engineering is a systematic method of developing and comparing alternatives that will provide all the essential functions with the greatest value (greatest efficiency, economy, quality and the least delay). This analytical method produces recommendations, not decisions.

A multi-disciplinary team is gathered, including a facilitator, to study the particular topic in question. The members of the team chosen usually have relevant expertise but little, or no, first-hand experience of the topic to be studied.

The steps in the process, as used by the US Bureau of Reclamation (USBR) involve;

- Information Gathering - Involves identifying the problem and gathering relevant information.
- Creativity - Involves "brainstorming" a large number of alternatives which could satisfy the requirement.
- Analysis - Involves reviewing the ideas generated and ranking them in order of potential.
- Development - The best ideas are now developed in sufficient detail to show their respective relative advantages and disadvantages and to be presented to the plant owner.
- Presentation - The team's findings and recommendations are presented to the plant owner with a candid and critical discussion around each alternative.
- Implementation - The owner determines which alternative will be accepted (on whole or in part) and estimates the benefits.

The USBR has found that when comparing the benefits (i.e. the savings portion) of the study to the cost of the study, the benefit cost ratio is often in the order of 10 or 20 to 1. This ratio can understate the real value of the study due to the non-monetary improvements such as quality which are not included.

7.5 Evaluate Issues

Previous steps in the feasibility process have focused on the technical condition and performance of the plant. There are other issues that require evaluation which are not purely technical and are considered in Step 7-5.

Environmental and Social Impacts

The feasibility of the environmental and social impacts of the alternatives under consideration needs to be evaluated. It may be that, for all the technical and business benefits available, the effects of the proposed changes will not be acceptable and will not gain approval in the relicensing process. More information on the approach to environmental and social impacts is found in Volume 6.

An environmental impact assessment will generally be required to determine if the proposed works will alter the existing impact of the facility on the environment.

A general discussion on the effects of modernization on environmental issues is presented in Section 2.3.3. These include:

- Any change in water use pattern
- Effect on water quality
- Effect on fish—habitat and population
- Effect of any additional construction

At this stage the environmental assessment will be of a preliminary nature to determine the practicality of proceeding to a full scale process within the relicensing process. It covers all avenues that would be explored in the FERC process and make a realistic determination as to the probability of success. The assessment tests all scenarios that are under consideration.

The assessment is best conducted by qualified professionals with intimate knowledge of FERC requirements and its decisions. This will usually be a consultant although the expertise may be available internally.

The social impact of the proposed options requires assessment but may require two trains of thought. The first is the effect of the proposals on third parties, i.e. the public, whilst the second is the effect on the workforce associated with the plant.

The social impact on third parties typically involves a change in water usage quantities and patterns and their consequent effects. Generally this is bound into the environmental assessment and licensing requirements considered in Section 6. The social impact on the workforce occurs with the effect of automation (if it is to occur under these options) and the resultant downsizing of the workforce. If a downsizing will occur then the costs and impacts of the process must be investigated along with the business benefits.

In some cases, it may be argued that the two aspects of social impact are linked but, in the case of a hydro plant, the usually small size of the workforce does not greatly affect the broader community. If a similar downsizing, on a percentage basis, was to occur in a thermal plant in a rural area then there would be a social effect on third parties caused by the downsizing due to the loss of economic activity.

Social impacts may also include the change in the plant's contribution to the economy, in terms of taxes, grants and water rentals, that will occur under the proposals being investigated. The way in which these impacts are considered will depend upon the status of the owner, i.e. a government owned or privately owned corporation.

The assessment of the social effect on third parties of the proposals would usually be incorporated as part of the environmental assessment. The internal social effect would normally be studied internally by a human resources nominee.

Regulatory and Licensing Requirements

The investigation of the feasibility of satisfying regulatory and licensing requirements is closely tied to the environmental and social aspects mentioned previously. If these requirements cannot be satisfied then there is no point to continuing the process of assessing the feasibility.

Most owners will have some experience of the licensing process and its requirements but they may not be up to date with recent events. If there is any doubt as to the internally available expertise then a consultant with the appropriate qualifications should be engaged to advise on the process.

The study should consider the licensing and regulatory requirements as set out in Section 6.0 associated with the proposed modernization and the likelihood that these will be compatible with the technical and business aims of the process. These items should have been addressed in a preliminary fashion during the formulation of the various options to be considered in Section 4 with any items that were obviously not achievable being discarded at that stage. At this stage, however, a detailed evaluation of the requirements is needed.

If it is considered that there will be no problem meeting licensing requirements there is still the question of the time involved to gain final regulatory approvals. This interval can extend over periods of 2 to 3 years and this should be factored into the project schedule. No major funding commitments should be made towards the project until regulatory approvals are confirmed and any foreseeable appeal avenues exhausted, unless the risks associated with expending resources prior to regulatory are evaluated and accepted.

Risk and Insurance

Risk management is the ability to balance risks with the potential gains by making wise decisions.

As part of Feasibility, it is advisable to assess the risks associated with each option. Each risk, along with the potential mitigation available, can be identified. Risk areas to be considered include are included in the following box:

AREA	RISK
Technical and technological	• Proposed modernization activity does not work • New equipment does not meet performance levels • Technology changes make modernization obsolete • Inadequate assessment of condition • Incorrect designs and inadequate QA • Once work is initiated, more is identified
Construction	• Cost overruns • Delayed schedule, longer outages • Consequent damage • Contractor unfamiliar with specific work • Poor estimates of cost
Environmental	• Impacts on land/water due to construction • Pollution and spills
Operating	• New operation rules not written • New operation methods not attainable • Operation changes not acceptable by external stakeholders • New operation does not achieve expected gains
Hydrologic	• Water not available • Power studies inaccurate • Flow measurements incorrect
Revenue	• Value of products and services over estimated • Market does not exist for new products and services
Licensing	• Licence renewal refused or rights lost • Some existing water or flexibility lost during licence renewal process

Some of the risks identified for particular options may be unacceptable to the plant owner and the option in question may be discarded if suitable, cost-effective mitigation is not available.

Part of the mitigation available for certain risks identified may include insurance. The cost of the insurance, however, may be prohibitive. Investigation of the insurances available and the cost of the insurance will be a matter for each owner and their individual situation.

Ultimately the risks identified by this process need to be examined for their acceptability. If some risks are apparently unacceptable as they stand then the mitigation available to reduce the risks to acceptable levels have to be identified. If the cost of mitigation is uneconomic then the risks are confirmed as unacceptable and the project or activity is not feasible. If the mitigation can reduce risks to an acceptable level at an economic price, then the costs of this mitigation will be included in the financial evaluation conducted during the feasibility study.

7.6 Evaluate Options

The data collected during Steps 7-2 and 7-3 require evaluation to determine the final make-up of the options that will be optimized using the financial model in Step 7-7. The additional data assembled makes it possible to better identify the work items proposed for inclusion as the scope of work, costs and benefits of each item have been more accurately determined. The various work items can be assembled into viable options to be evaluated by the financial model.

In some cases the additional data will shed new light on the whole process and the option that moved forward from the formulation of the Modernization Plan will have to be reconsidered. For example, if an item of equipment is more seriously deteriorated than when initially investigated, or its performance is worse than originally measured, the cost of replacement or repair may be higher than expected, or the case for modernization may become more attractive. Alternatively, the outcome of the power study may be more, or less, attractive than first estimated with commensurate impacts on the attractiveness of modernization.

Example

The No. 1 Unit has been assessed for potential life extension and also modernization improvements. During the formulation of the Life Extension and Modernization Plan in Section 4 the following was identified:

- These is a potential to uprate the turbine using a replacement runner with improvements forecast of approximately 2.5 MW in output and 4% in efficiency. Remaining life of the runner is assessed at 12 years.
- There is also potential to uprate the generator by:
  - 1 MW by operating at closer to design limits
  - 3 MW by rewinding with modern insulation materials

  Remaining life is assessed at 8 years but further testing is suggested.

These options have been moved forward to a Feasibility Study with additional information being gathered:

- Turbine runner model testing revealed that the 2.5 MW potential increase in output forecast was realistic. Testing results, however, now forecast average efficiency improvements of 5%. The remaining life assessment has stayed at 12 years.
- Generator remaining life has been assessed at 5 years following partial discharge analysis and insulation resistance test.

Options to be considered now include:

- Do all works now, i.e. runner upgrade and generator rewind
- Defer all works for 2 years
- Do all works in 5 years when the generator is due for rewind
- Uprate runner now and operate generator at higher limits until rewind due

All these options now require evaluation in Step 7-7.

Cost Estimates of Each Option

Previously, generic data was used to develop cost estimates. At this stage of the process, more detailed cost estimates are required to allow meaningful and accurate comparisons of options. Dependent upon the structure of the owner's organization, these costings may be available from in-house sources, manufacturers, specialists or consultants.

Feasibility estimates may be made after enough engineering work has been done so that sketches, plans and drawings showing some project details and dimensions are available, and the specifics of equipment and/or systems have been determined. The estimates will enable economic, technical and regulatory feasibility to be established or evaluated. The estimating methods that may be used are set out in Section 2.3.5.

Dependent upon the size and type of project and the extent of information available when the estimate is prepared, feasibility estimates may differ from the final project cost by between 17.5 to 25%.

The capital cost of the project is estimated by including costs for all of the following, that are applicable:

- Engineering and Design
- Project management
- Regulatory and licensing
- Procurement
- Equipment
- Installation/construction
- Commissioning
- Lost generation and capacity
- Financing
- Interest during construction
- Contingency
- Escalation
- Corporate and other indirect
- Risk mitigation
- Workforce impact

The estimates applied to each option need to be applied consistently. All activities common to each option require identification to ensure identical costs are being used.

Benefits of Each Option

The benefits of each option need to be identified in a similar way to the costings above. The benefits are evaluated on a portfolio basis as some of the benefits generated as by-products of the option may have value in some situations but not in others. For example, black start capability may be gained from modernization and, if looked at from an individual plant level, may be a valuable product. However, on a portfolio basis, there may be no requirement for additional black start capability and therefore this product adds no value.

Benefits are the products and services which are measurable and which have a monetary value, including:

- Increased product output
- Increased variety of products available
- Increased flexibility of operation
- Decreased operating and maintenance costs
- Improved environmental performance
- Improved safety performance

In some cases the value of benefits may be difficult to determine. A consistent, systematic approach to the valuation will reduce the risk of errors. Some hydro plant owners are using non-monetary benefits in their decision-making process. This is discussed in general terms in Section 5.

7.7 Optimize Options

The economic evaluation performed during Feasibility documents the project benefits and helps to select the plant modernization modifications to be made. The results of the feasibility analysis can be used to obtain project approval for the funds required to perform the work or purchase replacement equipment.

The economic evaluation will use the example evaluation template (the ‘Model’) described in Section 4. During feasibility, more accurate information developed in Steps 7-2 to 7-5 will be used as input. This will result in more accurate outputs from the Model.

The Model estimates the value of the plant to the utility over the next 20 years, with the flexibility to adapt to changing market conditions. Life extension and modernization plans for a particular plant are evaluated by comparing the key financial indicators that are outputs of the Model. The Model has been developed so that all utility costs and revenues, from all business units, can be allocated to the plants. The Model is shown schematically in Figure 7-2.

The output of the Model will nominate the expected returns for each of the options it assessed. The results will allow the options to now be optimized to determine if the proposed return can be improved further.

The optimization will include any adjustments to the inputs of the Model in terms of changes in product mix and costs. This process is not intended primarily as a sensitivity analysis; rather as a way to determine if there are other and better solutions available.

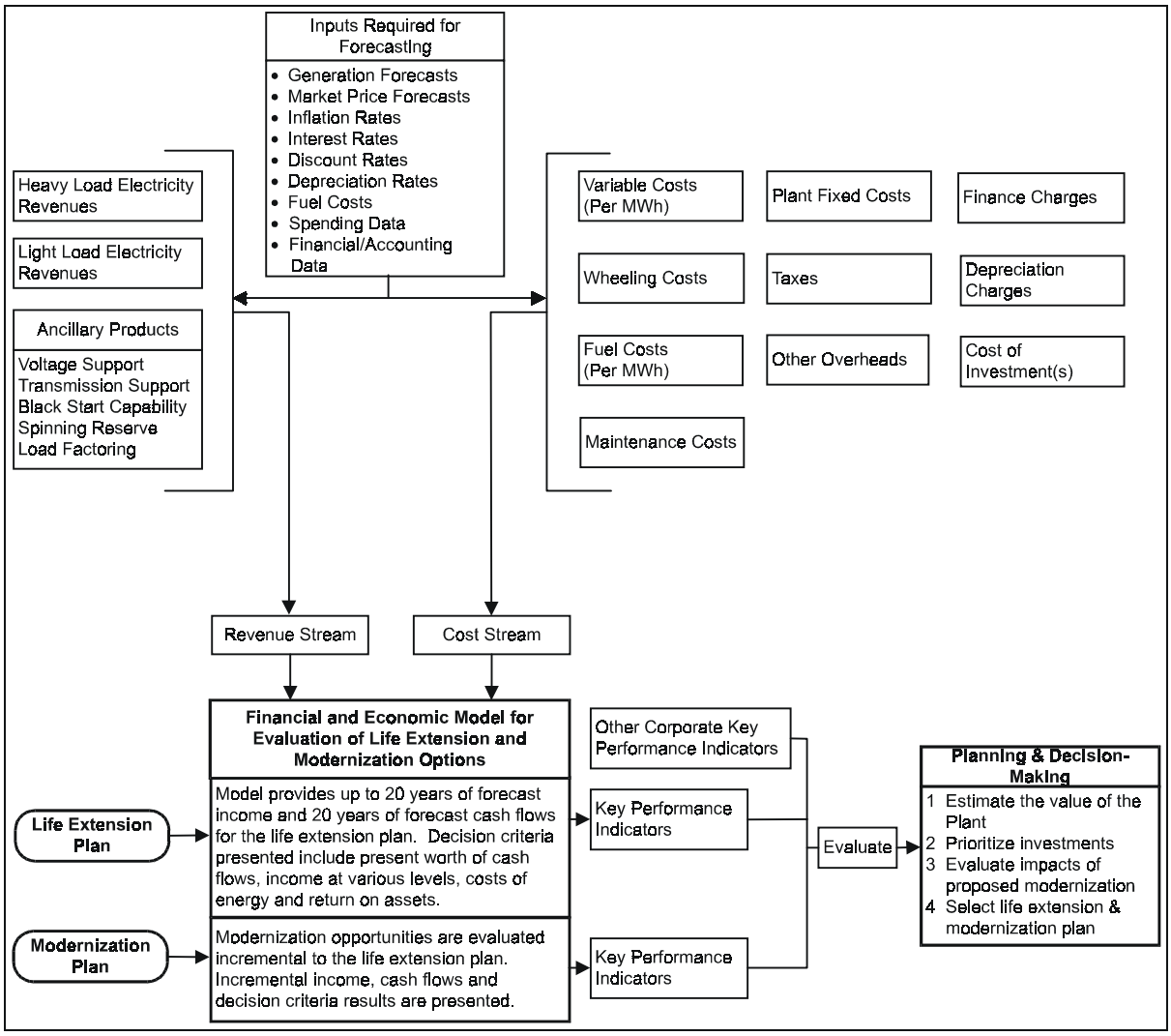

Inputs Required for Forecasting
• Generation Forecasts
• Market Price Forecasts
• Inflation Rates
• Interest Rates
• Discount Rates
• Depreciation Rates
• Fuel Costs
• Spending Data
• Financial/Accounting Data
Heavy Load Electricity Revenues
Light Load Electricity Revenues
Ancillary Products
Voltage Support
Transmission Support
Black Start Capability
Spinning Reserve
Load Factoring
Variable Costs (Per MWh)
Plant Fixed Costs
Finance Charges
Wheeling Costs
Taxes
Depreciation Charges
Fuel Costs (Per MWh)
Other Overheads
Cost of Investment(s)
Maintenance Costs
Revenue Stream
Cost Stream
Financial and Economic Model for Evaluation of Life Extension and Modernization Options
Model provides up to 20 years of forecast income and 20 years of forecast cash flows for the life extension plan. Decision criteria presented include present worth of cash flows, income at various levels, costs of energy and return on assets.
Modernization opportunities are evaluated incremental to the life extension plan. Incremental income, cash flows and decision criteria results are presented.
Life Extension Plan
Modernization Plan
Other Corporate Key Performance Indicators
Key Performance Indicators
Key Performance Indicators
Evaluate
Planning & Decision-Making
1 Estimate the value of the Plant
2 Prioritize investments
3 Evaluate impacts of proposed modernization
4 Select life extension & modernization plan

Figure 7-2
Process and Data Flow of the Electronic Evaluation Template

7.8 Develop Approach to Modernization

The modernization option that is most attractive, and meets the minimum criteria set by the owners for an acceptable return, is selected for project definition/implementation. At this juncture, a complete picture of the proposed project is formulated and summarized.

This will involve the use of more detailed information than was gathered during the evaluation stage as the focus of the project narrows further. The data gathered will be used to formulate the Feasibility Report.

During this investigation it would be expected that the refinements brought about would improve the level of confidence in the feasibility of the project. If the value of the project appears to decrease and put feasibility in question, a return to the evaluation stage may be warranted to reassess all options.

The proposed project is now documented. This defines the modernization project and would include:

- Description of the work proposed
- An estimate of project costs, benefits and schedule
- A summary of licensing and any other issues
- A finance, risk and insurance plan
- An implementation plan

Description of Modernization Project

As a basis for estimating costs and justifying the project a clear description of the work proposed is necessary. This would include a description of all the equipment proposed, its size, rating and expected outputs. It would also include any structural changes proposed.

This information would be documented and accompanied by layout drawings and preliminary specifications.

Project Costs, Benefits and Schedule

The data used for the evaluation of the various modernization options will be able to be refined further in some instances.

Project costs will be further investigated now that the most attractive option has been selected. More detailed costs will be sought from manufacturers, detailed construction planning studies may be prepared and financing more thoroughly investigated. The estimates prepared may differ from the final project cost by between 5 to 15%.

Project benefits will be revisited but the level of refinement available will be limited as the information used in the previous step of the process would mostly have been the best available. More detailed performance estimates may be obtained from manufacturers for items such as turbine runners, generators and transformers which will assist in refining energy estimates.

The project schedule can also be detailed and optimized. The amount of float previously built into the schedule may be reduced in line with the extra detail being used in the project costs and benefits. Intermediate steps may be inserted between the milestones to help build a more detailed picture and determine if there will be any timing problems with the program proposed.

Financing, Risk and Insurance Plan

The financing, risk and insurance plans can be examined and expanded further. The depth and focus of the financing plan will be dependent upon the owner's approach to funding the project. The financing of the project by external means will require an in-depth analysis which will be built into the Feasibility Report.

The risks previously identified will be able to be refined and detailed. If, at this point, a more detailed identification and analysis of the risks shows that the risks are greater than previously estimated, then the selection process would have to be revisited. The insurance plan for the option selected is also open for further investigation.

Implementation Plan

An implementation plan is also formulated at this time to set out the way in which the project will be conducted to ensure its successful conduct and prompt completion. The plan will detail how the following elements will be conducted:

- Licensing amendments
- Financial planning
- Engineering
- Procurement
- Construction
- Documentation

7.9 Document Results

The feasibility report rolls up and brings to a close the selection and evaluation process of the Feasibility Study. It is the documentary basis on which the project will proceed. The report is a stand alone document which sets out the existing operation and summarizes all the investigations carried out and the costs and benefits of all options. There will be a great deal of supporting documentation underlying this report which may be included as appendices for future reference. These include:

- the improved Condition Assessment
- details of any additional testing
- power study analysis
- buildability assessment
- risk assessments
- detailed estimates of costs and benefits
- financial modelling results

By including all this information with the report, it will be easily located in the future when the process is revisited.

8
PROJECT DEFINITION AND IMPLEMENTATION

Previous sections of this Guide provided information for the user to identify, evaluate, and select an appropriate modernization plan and confirm the feasibility of selected activities. This section assists the user in formulating a general plan of action and implementing this modernization plan. The activities to be performed during the project definition implementation phase are set out in Figure 8-1 below.

A summary of all activities, their expected duration, range of costs, and responsibility is presented in Table 8-1.

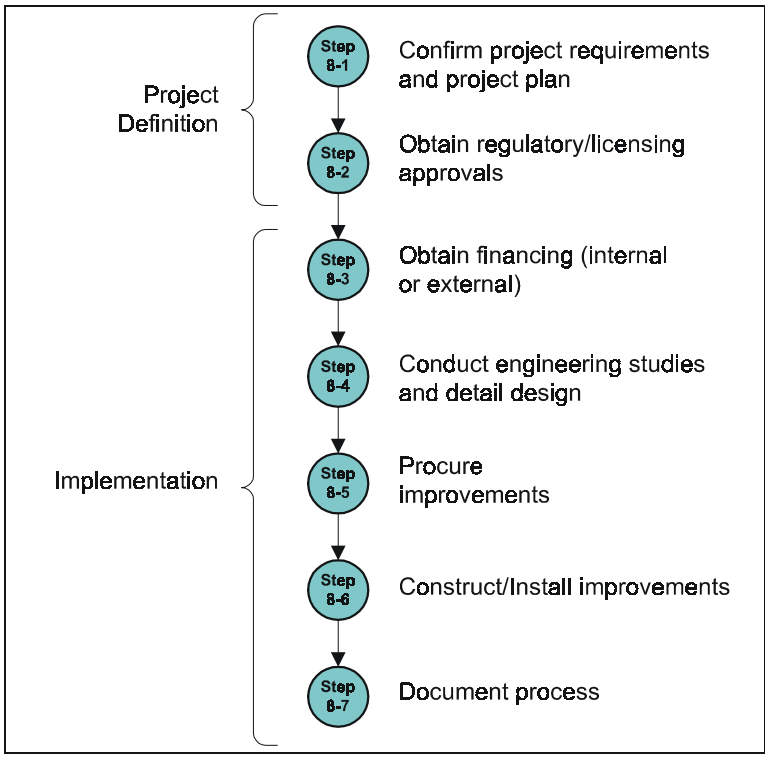


Figure 8-1
Implementation

Table 8-1
Implementation

ACTIVITY	PERFORMED BY	DURATION	COST
Licensing:			
• Prepare FERC License Amendment	Owner and/or Consultant	- 1 to 4 months	$20,000 to $200,000
• Receive Amendment		- 1 to 2 years (Refer to Section 6.0)	$50,000 to $1,000,000
• Receive Relicence		- 2 to 3 years (Refer to Section 6.0)	
• Obtain other permits	Owner and/or Consultant	- Concurrent with FERC License	
Financial Planning:			
• Establish financial feasibility and secure short-term and long-term funding.	Owner and/or Consultant/Financial Advisor	Concurrent with licensing	Cost of funding 1 to 3% of total direct cost
Engineering:			
• Prepare detailed designs, specifications, and engineer's estimate.	Owner and/or Consultant	3 to 12 months	5 to 10% of direct cost
Procurement:			
• Equipment tests and selection • Prepare contracts • Invite tenders • Evaluate tenders and award contract • Manufacturing • Procurement quality control	Owner/Consultant/ Manufacturer	3 to 12 months	
Construction:			
• Transport to Site • Construction and Installation • Testing and Commissioning	Owner/Manufacturer/ Consultant/ Contractor	1 to 3 years	
Documentation of Process:			
• Design Reports • Manufacturing Reports • Transportation Reports • Construction Reports • Inspection, test, commissioning and acceptance reports • Operating and maintenance manuals	Owner/Consultant/ Manufacturer/ Contractor		

The project definition phase is the connection between the completion of Feasibility (Section 7) and the implementation of the Modernization Plan. The activities in the project definition phase are vital to the success of the project as the regulatory/licensing and financial approvals are crucial steps prior to implementation. If these are not in place, the project will not proceed.

During the project definition and implementation phase, the following activities are carried out:

- Project management
- Engineering
- Procurement
- Construction

- Construction management
- Testing and commissioning
- Documentation

The selection of people to do the work will depend on the resources available and contracting philosophy of the hydro plant owner. All project activities may be carried out by the utility's own engineering, maintenance and construction staff or all or part of the work may be contracted out.

Some points to consider relating to management issues during implementation include:

- Allocate a specific Project Manager, task managers and a project team. The activities are much more than a series of maintenance projects and should therefore not be undertaken solely by the maintenance and operations staff. They can assist with the projects but their regular activities must not be affected. However, it is a good idea to include local operating staff in the implementation team. They know the plant condition and functionality and can greatly assist in safe and efficient implementation. They can also assist with operator training for the new assets.
- Drawing control should be carefully managed. There will be more modifications to drawings than at any other time in the life of the plant. It is important that the latest authorized drawing copy is on site, and that drawings for works as built are quickly completed and issued.
- Change control generally is an issue on modernization projects. On site design changes always occur when retro fitting new technology to old assets.
- Co-ordinate the plant and project works management systems.
- Elect a 'Client's Representative' who is familiar with the facility layout, operating requirements and risk exposure.

With all implementation scenarios, it is critical that the scope of the project be clearly and completely defined and that budgets and schedules be established for each project activity. Throughout the project duration, the status of actual versus budgeted costs and schedule progress are monitored and reported. Should cost overruns or schedule delays be forecast, immediate corrective action is taken in order to minimize the problem.

Throughout the implementation phase of the program, hydro plant owners may also introduce new or enhanced preventive or predictive maintenance programs as part of life cycle management. At the same time, attention is given to providing staff training both to meet the increased demands of an enhanced maintenance program and to properly operate the modernized plant. Finally, owners typically require modernization of their spare parts procurement and inventory systems to match the modernized plant and maintenance procedures. These improvements are also part of the implementation phase.

Technical Volumes 2 to 7 provide useful information for the activities which comprise project definition and implementation.

8.1 Confirm Project Requirements and Project Plan

Feasibility will have selected a modernization approach and proved its technical and financial viability. The first activity in the project definition and implementation phase will be to confirm that this approach meets the overall requirements of the owner before proceeding.

One way to address these requirements is through the standard project management approach. This includes a Statement of Objectives, accepted by the sponsor of the work. An example of this is given in Table 8-2.

These objectives are incorporated into the project management process as part of the development of a Project Plan. This document is the outline of how the project will be undertaken and includes a summary of responsibilities, authorities, costs, schedules and deliverables. The Project Plan will also include a Quality Plan to guide the process.

The Statement of Requirements contained in the Statement of Objectives can be used as the record of the approved User Requirements. On larger projects, a more detailed User Requirements document will be required to cover all aspects of the project. The value of a well documented description of how the plant is presently operated, and how it will be operated after modernization, will be seen during licensing consultations and contract scoping.

Table 8-2
Sample Statement of Objectives

Hydro Plant Modernization Project

1. PROJECT DATA

1.1 Standard References

- Project Title
- Originating Organization
- Project Sponsor

2. SCOPE OBJECTIVES

2.1 Statement of Requirements

The Modernization Plan for the Project concluded that upgrading all four of the turbines in Powerhouse No. 1 is attractive. These units are impulse turbines manufactured by Pelton in 1958. The selected manufacturer of the upgraded turbines has estimated that an increase in efficiency of about ___% can be achieved in these turbines by replacing the runners and refurbishing the nozzle assemblies. The estimates are based on turbine efficiency tests carried out in 1993 on Unit 1. The Unit 1 efficiency tests are representative of Units 1-4 which are of identical design.

Upgrading of the Units is estimated to increase energy output and plant capacity by ___ GWh and ___ MW respectively. The manufacturer has provided budgetary prices, guaranteed within +5% and -10%, for the runner upgrades. Based on this, unit cost of average energy produced as a result of the upgrades is estimated ___ cents/kWh. Current market forecast price of electricity over the next few years is about ___ cents/kWh.

The summary requirements for the Implementation Phase of the Modernization Project are stated as followed:

2.1.1 Initiate procurement of turbine runners.

2.1.2 Confirm efficiency gains achievable with turbine upgrades through appropriate model and prototype testing of both existing and upgraded runners.

2.1.3 Subject to confirmation of efficiency gains and business case justification, carry out work necessary to upgrade one or more runners.

2.1.4 Complete the work in accordance with the approved User Requirements document.

2.2 Results to be Achieved

2.2.1 The deliverables are:

- Statement of Objectives, Project Plan and Project Approval for the Implementation Phase of the project
- Request for Quotation (RFQ) for turbine upgrades
- Report(s) on laboratory model tests on existing and upgraded turbines
- Business case(s) for upgrading one or more turbines as appropriate
- Confirmation of project and Purchase Order signed
- Upgraded units fully operational
- Report on efficiency test(s) of upgraded units
- Reports showing project status

2.2.2 Supplementary Items

- None specified

Table 8-2
Sample Statement of Objectives (continued)

3. SCHEDULE OBJECTIVES

The target dates for milestone events for the project are:

Description Date

- Statement of Objectives (Implementation Phase) Approved
- Issue RFQ
- Sign Purchase Order
- Upgraded turbines in service
- Implementation Phase complete

4. COST OBJECTIVES

The target total costs for the project are:

- The target cost, up to the point of proving the business case to justify proceeding with manufacture of the first runner, is $_____.
- The total target cost for upgrading all turbines is $_____.

5. APPROVALS

_____ is appointed Project Manager with authority and responsibility in accordance with the Project Management Policies and Procedures of _____.

Initiator:	_____	_____
	Name, Title, Organization	Date
User:	_____	_____
	Name, Title, Organization	Date
Sponsor:	_____	_____
	Name, Title, Organization	Date
Accepted by:	_____	_____
	Name, Title, Organization	Date

8.2 Obtain Regulatory/Licensing Approvals

Licensing is crucial part of any modernization process. The remainder of the project can be effectively at a standstill while the relicensing process is in progress. Any decision to fast track detailed engineering works in parallel with relicensing proceedings requires careful consideration of the possible risks and benefits. There is the possibility that the conditions imposed in awarding the updated licence may require review and re-engineering of the original proposed project. There is also the possibility that the modernization proposals are not given approval, in which case the work will cease.

A step-by-step approach to developing a regulatory approvals and licensing plan is contained in Section 6. It covers FERC processes and other permits necessary.

8.3 Obtain Financing (Internal or External)

Cash flow requirements and the method of funding the modernization project are confirmed during the project definition phase.

Cost estimates developed during Feasibility for the selected modernization project can be used, in conjunction with the information developed in Steps 8-1 and 8-2, to estimate the project's capital requirements.

The cost estimates and milestone schedule are used to determine the cash flow requirements to meet the schedule activities.

Selection of the project's funding method will depend on the owner's financial philosophy. To determine the percentage of working capital and short and long-term debt to be used for the project, financial planning is undertaken concurrent with preparation of the licensing and permit applications.

Generally, all internal approvals and external regulatory/licensing approvals will be in place prior to expending funds in detailed engineering studies and contract document preparation, subject to the individual strategy for the particular project (refer to Step 8-2).

8.4 Conduct Engineering Studies and Detail Design

At the conclusion of the relicensing process, detailed engineering works may proceed, if they were not carried out in parallel with the relicensing process.

The engineering activities performed during the implementation phase consist of detailed design work for the modernization activity. This design work includes preparing design drawings, analysis and upgrade requirements of affected components, selecting equipment, and preparing the detailed design requirements for purchased components and construction.

Additional Tests and Studies

Following approval to proceed, and depending upon the scale of the modernization project to be implemented, it may be desirable to undertake additional testing and studies. Additional testing has the purpose of optimizing design and improving the benefits of the modernization process.

Example - Physical Hydraulic Model Tests of Turbines

Hydraulic model tests of turbines are carried out for three main purposes:

- To test whether the improvements indicated by the efficiency tests, designs and mathematical modelling can be achieved.
- To optimize design by physical changes to both the runners and the water passages.
- To provide a basis for contractual performance specifications.

The work is normally undertaken by turbine manufacturers or independent hydraulic laboratories. In the case of competitive model testing, to select between two or more manufacturers, more than one model will be tested.

The costs of the hydraulic model tests are borne by the hydro plant owner. For this reason, model tests are usually limited to units of about 50 MW or greater. The gains that could potentially be achieved by modelling smaller units would be unlikely to cover the costs of testing.

Another example of this procedure would be performing a detailed waterhammer analysis if an increase in flow is included in the Modernization Plan. The results of the analysis are compared to the design parameters of the penstock, spiral case, inlet and affected components to confirm that the design criteria are not exceeded.

Detail Design of Infrastructure

Detailed design of the infrastructure for the project can now proceed. It is essential to check that the initial assumptions of buildability (refer to Step 7-2), are correct.

Examples of the detail design process include:

- Plant arrangement drawings locating the equipment components and confirming any space or interface requirements.
- Detail drawings showing any piping or structural changes to the existing powerhouse.
- Diagrams such as plant metering, relaying, one-line and controls and instrumentation define any electrical modifications and the design standard to be achieved.
- Wiring drawings showing the interconnection requirements.
- Conduit and cable tray drawings route cable between items of equipment.

Standard Designs

It is generally advantageous to incorporate as many standard design features as possible into the project. The use of standard designs makes the layout of the modernized plant easier and may assist in the long-term with the replacement of parts such as electric motors and controls. Also standardizing as many components as possible will allow smaller inventories of spares to be carried and limit the breadth of expertise required to maintain the plant.

8.5 Procure Improvements

Procurement activities for implementation include:

- Preparing bidding documents
- Inviting and analyzing bids
- Awarding the contract

The bidding documents define the technical requirements and commercial terms for each procurement package and establish a common basis for competitive bids. Prior to the solicitation for bids, qualifications of prospective bidders may be reviewed and a list of bidders selected but this step is optional and often not used.

A bidding period, bid evaluation, and contract award conclude the procurement process. An analysis is performed to compare the bids with the requirements of the bidding documents and to determine the relative merits of each bid. The conclusion of the analysis is a recommendation concerning the contract award.

Procurement Options

A philosophical decision by the owner is required at the commencement of the implementation project concerning the manner in which the modernization will be executed. Regardless of the traditional approach within the owner's organization, each new project provides an opportunity to revisit the options available to complete a project. Refer to Section 2.3.4 for further discussion.

Technical Specifications

There are options available as to the type of specification used in the procurement process. In broad terms the options vary from the performance type specification to the detailed specification. The number of contracts and the way in which they are used depends upon the procurement option selected but there are many variations available. Refer to Section 2.3.4 for further discussion. Examples of technical specification criteria are found in Volumes 2 to 7.

Whichever type of specification is chosen, it should be structured in such a way that allows bids to be assessed in a convenient fashion and compares "apples with apples". The specification should also permit the bidder to propose innovations as alternatives as long as a conforming bid is submitted for initial consideration.

Risk Sharing - Bonuses, Penalties, Liquidated Damages

The commercial requirements of the specification have the ability to be very flexible. Again, the owner may have a traditional approach which will not alter the project in question but there are innovative alternatives available to traditional approaches which share risk and provide contractors with incentives to be innovative and implement techniques which will add value to the project. The value may be added in terms of improved performance over that specified or shorter outage times which reduce lost generation costs.

The incentives offered tend to be in the form of a percentage of the improvement being given to the contractor as a bonus payment. The structure of the bonus is formulated in such away that it cannot cost the owner more than it is worth. The basis of the measurement of the improvement must be agreed prior to the contract being awarded.

Penalties can also be built into the specification in a similar fashion. If the contractor provides a product that does not perform as specified the penalties may be fixed or applied on a sliding scale.

Similarly, program overruns would generally be dealt with by applying liquidated damages. Caution should be applied with the application of liquidated damages as generally the owner must be able to show actual losses that are caused by the program overrun for the damages to be applicable.

Invitation to Tender

Selecting a contractor may generally be carried out in a one, two or even three stage process dependent on the nature of the project and the size and type of contract envisaged. The one step process is the most common and simply involves the issue of tender documents to the open market with tenders being accepted from any party.

The two step process generally uses an Expression of Interest (EOI) process and, if utilized, will be used for projects where special expertise is required and large expenses will be incurred by bidders in the tender stage. The EOI process outlines the scope of work required and identifies companies that are interested in bidding for the contract along with their expertise and experience. A short list of bidders is selected from the proposals received using the following parameters:

- Experience in carrying out this class of work
- Performance in meeting schedules
- Financial position
- Ability to obtain bid and performance bonds, insurance, etc.
- Availability of qualified staff
- Quality assurance procedures
- Plant and field equipment
- Environmental record

The short listed companies to receive tender documents is formulated and tender documents are distributed to those selected companies only. The advantage of this process is that having a limited field of bidders assures each bidder of a reasonable chance of recouping their tendering costs and allows them to expend a suitable amount of effort on the bid. The result for the owner is generally more competitive bids and an associated cost benefit.

There will be occasions, particularly in the area of larger turbine runners, where a three step process may be used. A short list (generally of two bidders) is created from the bids received in the second stage and the bidders will be asked to construct models of their proposed equipment to demonstrate in independent laboratory testing that the performance proposed will be achieved. The third stage will be treated as somewhat of a competition in an attempt to gain superior performance as the final result. Bidders' expenses during this stage of proceedings are generally covered by the owner.

It is important to allow sufficient time for bidders to formulate their pricing for the specification. If bidding periods are too short the loser from the situation will be the owner, which will pay a premium for the product as bidders have not had sufficient time to be confident of their pricing and will attach a risk premium to their price.

Evaluation and Award of Contract

The bids received from the tendering stage should be evaluated in such a manner that all bids are evaluated on a "level playing field". That is, what the bidder is offering must be comparable to all other bids and also must satisfy what the owner wants. Using price alone as the determining parameter is a dangerous course of action to follow as the final product may not be what the owner expected. Areas to be considered should include:

- Price
- Expertise offered
- Equipment and performance offered
- Schedule proposed
- Quality system proposed
- Exceptions to tender

Qualifications submitted by tenderers with their bids are closely examined for their effect on price. In most cases, the owner will request the qualifications be withdrawn from the offer to allow accurate comparisons of the bids. If the qualifications are not withdrawn, estimates, to assess the value of the qualifications, may need to made by the staff examining the bids to allow evaluation to proceed. It would be unusual if the qualifications submitted with the bid were favourable to the owner.

All unknown bidders on the short list are evaluated. Following are typical aspects of individual bidders, subcontractors, and members of a joint venture or consortium that are evaluated:

- Policy (quality, timeliness, delivery, environmental matters).
- Management.
- Organization.
- Financial situation.
- Personnel.

- Plant and equipment.
- Methods (quality management program, manufacturing and construction standards and procedures, manufacturing standards and procedures).
- Legal history (litigation or arbitration from contracts executed during the past 6 years).

The financial capacity of the bidder to undertake the works requested should also be investigated. If the bidder has insufficient financial backing the project may founder at an inconvenient moment at great expense to the owner.

Joint ventures are another area where the owner must make investigations prior to the award of a contract. The nature of the joint venture being proposed must be understood and the owner must be satisfied that it will be to the owner's advantage to enter into a contractual relationship with a joint venture company. Joint ventures, unless properly founded, have the potential to disintegrate due to internal (joint venture) problems that arise when external (contractual) problems occur. Each party connected with the joint venture has their own interest to protect and when trouble arises will proceed to protect their own interest usually to the detriment of the owner.

Prior to the award of the contract, the offer of the preferred bidder should be consolidated to ensure that all relevant information and post tender negotiations are included and that all qualifications have been removed leaving no doubt as to what is being contracted. This also includes the contract schedule.

The contract commencement date along with intermediate milestones and final completion dates will be defined and specified in the contract, either as a calendar date, a specified time after submission of tenders, or at the time that all specified conditions precedent have been satisfied.

8.6 Construct/Install Improvements

Construction activities include manufacture, construction, installation, and start-up. During the construction phase, the new or replacement equipment is manufactured to design drawings reviewed by the owner and/or engineer. When justified, turbine model tests may be conducted, if they have not occurred earlier, and witnessed to demonstrate the hydraulic performance of the replacement runner.

Alternatively, the basis of the prototype performance is reviewed prior to fabrication. Shop inspections of the equipment are performed to confirm the major controlling dimensions and quality of the replacement equipment.

Disassembly of the existing equipment is coordinated with the milestone schedule and replacement equipment deliverables to minimize lost generation. Installation of rehabilitated, replacement, or upgraded equipment is performed simultaneously with any structural modifications to the facilities. During this phase, construction management, if applicable, monitors, controls, inspects, and co-ordinates the work of the various contractors. Acceptance tests, to confirm the equipment and guarantees, complete the rehabilitation and implementation process.

Off-Site Manufacture and Quality Control

Manufacturing of components off-site requires monitoring by the owner to ensure that what was specified, or proposed by the contractor, in the contract is what is being manufactured. The quality system used by the contractor is an important part of this process but owners relying totally on the contractor's quality system run a risk that the final product may not be what was anticipated.

The use of hold points in the contractor's inspection and test plan (ITP), requiring the owner's representative to witness key points of the process, is a way of ensuring that a regimented approach to quality inspection by the owner is in place. When the owner is requested to insert hold points into the contractor's ITP it should insert sufficient points to ensure that it has a measure of control over the quality of the product. However, the effect to the overall program should be considered if the owner is unable to inspect the product when requested and production is halted until the product is inspected. The use of witness points for inspections considered optional and not vital, in lieu of hold points, is recommended.

Ensuring that off-site program is being met is also very important. If the program lags at this point then the viability of the entire project may be called into question if the equipment will not be ready for the outage to commence on site. Personnel experienced in the manufacturing processes being undertaken are important to the successful monitoring of the works.

Transportation to Site

Transport constraints and unusual requirements are usually identified in the earlier planning stages of the project. The early identification of site constraints allows bidders to incorporate them into their pricing and identify alternative means to mitigate the problem lowering the cost to the owner.

Allowances still have to be made on site to ensure that, when equipment is to be received at site, adequate preparations have been made to receive the equipment. This is important in the case of plants with limited space and storage facilities. This will involve an amount of co-ordination between the contractor and owner.

Owners should ensure that, if existing equipment is transported off-site for repair or modification during the modernization project, that they have adequate insurance coverage in place to cover the transport of the equipment. In some cases the insurance coverage in existence for the equipment may not cover the equipment being moved off-site.

"Incoterms", published by the International Chamber of Commerce, are available to allow transportation terms to be clearly specified and understood.

Installation and Construction

The installation and construction portion of the modernization project is one of the most difficult parts of the project to successfully complete. The potential for problems to occur, which may threaten the overall viability of the project, is large as this is the time when previously undetected mistakes manifest themselves and demand instant solutions. This stage of the project is also the most dangerous in terms of safety concerns and careful management is vital.

Scheduling of installation and construction works is an important aspect of the successful completion of the modernization project. The minimization of lost generation time of the plant to be modernized is a major cost saving. Outages of common equipment may affect more than the unit out of service. Operational and contractual considerations must be taken into account when these outages are being scheduled.

Construction Management

Contractual devices in place penalizing the contractor for non-performance, do not necessarily ensure the successful completion of the project. The recovery of these penalties from the contractor is always a torturous process and the amount recovered usually does not cover the owner's losses or inconvenience. The owner's construction management team has an important role to play in ensuring the smooth running and successful completion of site works.

The functions of the owner's construction management team depend on the nature of the contracts involved. Where a performance-based contract is in place, the owner's representative on site will not be authorized to supervise work. The owner's representative will maintain an interest in the quality of site works (as specified in the contract) and in site safety matters along with occurrences on site which will affect the progress of the project (e.g. industrial relations).

Where the owner (or its representative) is responsible for the design component of the project, the owner's representative will be authorised to supervise the contractor's activities. The owner's representative will also maintain the same interests as those in a performance-based contract.

The construction management team has the responsibility of monitoring quality and program. The team witnesses hold points as the owner's representative if a quality system is in place. Progress payments, if part of the contract, are assessed by the team for accuracy. Where areas of the work are in dispute the construction management team also represents the owner in quantifying the magnitude of the disputed work and verifying the quantity of the contractor's effort.

The construction management team can form a vital link between the contractor(s) and owner's operating employees in plants where there are other operational units. They are able to ensure the smooth coordination of shared ancillary equipment such as cranes and, in disputes, also keep the contractor's rights under the contract in mind to minimize overall costs.

Contract Management

Contract management works hand in hand with construction management. The construction management team is responsible for monitoring site works, while the contract management team is responsible for monitoring the contractual aspects. For example, the construction management team will advise the contract management team on the quantum of contract progress payments but the contract management team will arrange for payments to be made.

The contract management team will also arrange for contract variations and ensure that they are bona fide changes. Disputes concerning contract terms, retention monies and performance deficiencies will also be resolved through the contract management team.

Testing and Commissioning

The testing and commissioning stage of the project involves:

- Verifying the construction of the various systems that were modernized under the project.
- Testing these systems on an individual basis, including the measurements of pressures and other critical parameters.
- Testing the systems in concert with other related systems.
- Performing operational tests on the unit, both on-line and off-line, under various loads and verifying how the plant performs in emergency situations.
- Verifying the designed performance expectations (needs).
- Ensuring site staff are familiar with the plant's new capabilities.

The testing and commissioning portion of the project brings together all the pieces of the project and usually forms the successful conclusion of a long and involved process. It also has the potential to identify areas of poor performance of the project both on behalf of the owner and the contractor if deficiencies have not been identified during construction. PLCs and other new technology have a habit of poor reliability and unexpected behaviour during commissioning and early life. Measure and track the operating parameters to ensure the assets and personnel are not exposed to unacceptable risk. It is important that the owner has experienced representatives monitoring the performance of the equipment to ensure that the performance during commissioning is replicable during the day to day operation of the plant. Consideration should also be given to the use of an independent commissioning engineer, particularly if there are financial penalties for performance short falls.

From a safety perspective, this portion of the work can be amongst the most dangerous. The plant is often operated at its extremes to test its capabilities to the fullest and, with these events occurring for the first time, there is always a risk of an unexpected failure with a resultant risk to personnel and the plant itself. The intermediate stages of commissioning can also be dangerous as equipment is powered and operated, individually and in systems, for the first time and if a mistake has occurred during construction, it will now become apparent. The importance of a successful safety and quality system is highlighted at this point.

Disputes that arise over the performance of the unit at this stage should be pursued and finalized, if possible, before the unit is handed over and placed into full time commercial service. If further testing is required, or an additional inspection is required, it is easier to carry out these tasks before the unit is handed over rather than after the event.

The information gathered at this stage serves as the baseline performance of the plant for many years to come and there are obvious benefits to the information gathered at this point being as complete and detailed as possible. All information should be clearly documented and agreed to by all parties.

Training

Training of local staff in the operation and maintenance procedures should be completed before the modifications are commissioned.

8.7 Document Process

Documentation of the entire process is important for operational, maintenance, contractual and historical reasons. The extent of documentation produced and archived is dependent upon the scale of the work being undertaken.

From the operational and maintenance viewpoint, documentation in the form of operating and maintenance manuals, with performance information included, is important. This should be available before the modernized plant is commissioned. Concise manuals with plant descriptions, performance data, troubleshooting information and maintenance requirements are required for all altered equipment. This information could be presented in hard copy or electronically. The information should be incorporated into existing documentation where applicable. The use of manufacturer's "glossy" brochures for describing equipment (particularly smaller proprietary items) in lieu of purpose written documentation is strongly discouraged. Consideration should be given to the use of a specialist consultant for the compilation of operating and maintenance manuals.

From the contractual viewpoint, documentation is vital to the resolution of any problems that arise during the course of the project. Record keeping is a simple way of storing evidence of the contractor's activities on a day to day basis and is very useful when it comes to rebutting any case made by a contractor at a later date. The usefulness of this information is highlighted when contractor's claims for additional payment are received months and sometimes years after the event and staff have moved on to other projects or have left the company. Often diaries are the only physical evidence available of the contractor's activities and it is often the small, seemingly insignificant at the time, activities recorded in them that are the most useful in a contractual argument. Minutes of meetings are also important records as to agreements, or commitments, made during the course of the contract.

From a historical perspective the documentation collected during the modernization process can be a very useful tool the next time the process is undertaken for the plant. How many times during the course of the investigations into this modernization process has the team bemoaned the lack of information available to it? With the longevity of hydro plants it is likely that the modernization investigation process will revisit the plant in the future. So the information collected at this juncture will be a useful tool in the future - a snapshot of the performance of the plant.

The information on design, procurement, and construction is gathered as an ongoing process and included in a design/construction report. This includes photographs, as-built drawings, design criteria, changes, test results and deficiencies.

A
APPENDIX A: NEW TECHNOLOGIES

A.1 Introduction

Since the construction of hydro plants being considered for life extension and modernization, there have been many developments in the technology associated with the hydroelectric industry. The drivers for the use of the new technologies for modernization are:

- the many plants which are reaching the end of their economic lives and require decisions regarding their future.
- the increasing difficulty of constructing new hydro plants due to environmental and other regulatory concerns.
- resulting requirement to improve existing plants in preference to new ones.

The opportunities presented by the use of newer technology are that of improved profitability, reliability and environmental performance. They can be achieved through:

- increasing output and efficiency of the existing plant
- reducing operating and maintenance costs
- reducing the effects of the plant on the environment

In general, the use and development of computer-based technology has been a catalyst for enabling many of the developments outlined below.

The information in Appendix A is not a comprehensive guide to all new technologies nor a check list of items to be considered in any modernization project. Rather, it includes a series of signposts inviting investigation into areas that may be of benefit to the project under consideration. These can also facilitate a watching brief on options in case changing circumstances should make one of them become attractive. These signposts cover:

- Technical developments
- New materials
- New methods of testing
- New methods of analysis

Care should be taken when assessing these new technologies to carefully review the risks of departing from tried and proven technology to the new and innovative. Some of the technologies described in the following sections do not, as yet, always have a proven, long term track record.

A.2 Hydromechanical Plant

A.2.1 Turbine Runners

Improvements in turbine runners technology have been driven:

- The general requirement for increased power output and improved efficiency.
- The requirement to operate with greater flexibility to suit market needs by having equipment with higher efficiencies over a wider load range and eliminating "rough load zones", where operation was not previously possible.
- The search for increased availability and lower maintenance costs by reducing repair requirements due to cavitation, cracking and sediment abrasion.
- The requirement for enhanced environmental performance by improving fish survival rates, allowing small flows to be handled efficiently for riparian flow issues and maintaining acceptable water quality standards.

This has been achieved by improvements in:

- Design methods
- Modelling techniques (physical)
- Analytical techniques (power studies)
- Materials (stronger and corrosion/erosion/cavitation resistant)
- Manufacturing techniques
- Testing techniques (efficiency testing)
- Operational techniques (air induction to improve rough zones)
- Repair techniques

These improvements in runner technology have virtually ensured that with proper considerations, the replacement of an old runner will deliver greater power output at improved efficiencies. Capacity improvements of between 15 and 20% are possible[24] along with efficiency improvements of up to 10%.

Design

Numerical methods, using advanced computing techniques have allowed improvements in the design of runners and associated static components. Computational Fluid Dynamics (CFD) has facilitated detailed examination of the characteristics of fluid flow and optimization of runner design. CFD has improved dramatically over the last few years and, in many cases, can be relied

[24] Zaïkoff D.W., "Hydro-Québec's Comphrehensive Approach To Analyzing Power Plants For Upgrading" Uprating and Refurbishing Hydropower Plants V. Conference Proceedings. Not Published.

upon in place of physical hydraulic model testing. The investment required for physical testing is often not justified for units of less than 50 MW capacity and, in these situations, hydraulic engineers are relying upon CFD to new and existing designs.[25] Where physical testing is used, CFD enables runners to be optimized prior to any model testing and thus refine the model testing process.

CFD can assist in:

- Reducing swirl.
- Reducing the length of the hydraulic flow path in order to reduce skin friction.
- Reducing friction losses by optimizing the number of blades.
- Providing a smoother pressure change through the turbine.
- Eliminating low pressure spots in the turbine.[26]
- Enhancing fish survival.

The redesign of static components of the turbine is often carried out in conjunction with runner replacement to maximize efficiency gains from the modernization process. CFD techniques are also useful in this process.

Other techniques such as Finite Element Analysis (FEA) for stress analysis and Fracture Mechanics for materials optimization have also contributed to the development of improved runners.

Improvements implemented using design techniques and driven by environmental issues include:

- Enhanced fish passage survival rates.
- Improved dissolved oxygen levels.
- Efficiently providing minimum stream flows.
- Reduced oil and grease pollution.[27]

[25] De Henau V., Sabourin M., Labrecque Y., and Papillon B., "Hydraulic Turbine Design: Will Computer Simulations Replace Model Testing?" Hydro Review September 1998.

[26] Hawley N., "Prediction and Improvement of Off-Design Performance of Large Hydro Power Turbines" Hydropower Fluid Machinery FED-Vol. 136 ASME 1992.

[27] Fisher R.K., March P.A., Mathur D., Sotiropoulos F., Franke G., *Innovative Environmental Technologies Brighten Hydro's Future* presented at Hydrovision '98, Reno, Nevada, August 1998.

As a result of work by many parties, advanced program designs, such as the e-"fish"-ient ™ Kaplan design developed under a Department of Energy (DOE) program have appeared. The enhanced Kaplan turbine concept includes:

- High efficiency over a wide operating range with reduced cavitation potential.
- A gapless design for hub, discharge ring and blades for enhanced fish passage survival.
- A non-overhanging design for wicket gates along with environmentally compatible hydraulic fluid and lubricants.
- Greaseless wicket gate bushings.
- Smooth surface finishes in conjunction with upgrades for stay vanes, wicket gates and draft tube cone.[4]

An environmentally enhanced Francis turbine concept has also been developed under a DOE program with features including:

- A low turbulence, high efficiency design with reduced cavitation having a reduced number of blades compared to traditional designs.
- A non-overhanging design for wicket gates.
- Use of environmentally compatible hydraulic fluids for the governor.
- Greaseless wicket gate bushings.
- Upgraded surface finishes for stay vanes, wicket gates and draft tube cone.
- Adjustable speed generator for wide head range plants.
- An advanced control system for speed adjustment and/or optimized energy generation while operating units and the plant at flows maximizing fish passage survival when fish are present in the flow.[28]

Materials

The drivers of material property improvements have been:

- Cavitation, corrosion and abrasion resistance to improve component life and reduce outage rates.
- Increased strength to reduce runner weight and improve efficiency.
- Machinability which leads to improvements in power output efficiency as more complex shapes can be manufactured.
- Repairability (generally weldability) which reduces outage time by allowing welding and has also reduced heat treatment associated with welding.

[28] Fisher R.K., March P.A., Mathur D., Sotiropoulos F., Franke G., *Innovative Environmental Technologies Brighten Hydro's Future* presented at Hydrovision '98, Reno, Nevada, August 1998.

The evolution of materials has seen cast steel has been replaced with exotic alloys that are nickel or cobalt based and stainless steels, both martensitic and austenitic, which have greater cavitation resistance and corrosion resistance. Ceramics are also being used in the area. The use of polymers[29] for repairs is also being investigated.

Manufacture

The drivers of manufacturing improvements have been:

- The requirement to manufacture more intricate shapes to improve power output, efficiency and environmental performance.
- The requirement to consistently produce a quality item.
- The availability of improved materials which require new manufacturing techniques.

Major advances in the control, versatility, precision and accuracy of machine tools have resulted in considerably more accurate dimensions and fewer machining errors. In particular, computerized controls have enabled the accurate machining of irregular contours such as those on turbine runner blades. The resulting improvements in performance are:

- greater efficiency
- less hydraulic imbalance and less cavitation due to manufacturing errors
- Increased power output

Also, it is now possible to use the machining instructions created for the manufacture of the runner model and to translate these directly to be used for the machining of the full scale runner. This enables exact homology between the model and the finished product which reduces the possibility of differences in performance between the two runners.

Improvements in casting techniques and associated controls have resulted in castings with increased strength and toughness and with more uniform properties. In the case of cast turbine runners, this means that blade thicknesses may be reduced to improve runner performance.

Repair Techniques

Repair techniques for runners and associated static elements have advanced with the advent of techniques such as the thermal spraying of metals enabling thin layers of metals to be applied to parent surfaces and the new surface to then be machined. Weld materials and techniques have also advanced as previously mentioned but require heat treatment and stress relief to be successful. Water jet cutting is also used during repairs.

[29] Moss W.O., Morton R., "The Successful Solution to Cavitation Problems at Dinorwig Power Plant with the aid of Polymeric Coatings" Uprating and Refurbishing Hydro Powerplants V Conference Proceedings Vol. 3 1995.

The benefits of improved repair techniques have been:

- Reduced number of outages
- Reduced outage durations
- Reduced outage costs

Testing

The driver of testing improvements for turbine runners has been the requirement for more detailed information regarding the performance of both hydraulic models and in-service units.

Hydraulic models now provide more accurate and comparable test results due to:

- Improved measuring and computing techniques.
- Improved manufacturing techniques and the ability to exactly reproduce the model design as a full size runner brought about by computer aided design and manufacture (CAD/CAM).

Performance tests of in-service units have also gained in accuracy due to the introduction of more advance measuring tools which assist in the measurement of flows, pressures, temperatures, etc.

A.2.2 Governor

Governor upgrades are initiated because of the:

- Lack of spare parts for the existing governor (obsolescence)
- Automation of the hydro plant requiring it (modernization)
- Requirement to improve plant performance characteristics
- Need to improve environmental performance (oil leakage)

Governor upgrades involve moving from mechanical or analogue electronic systems to a digital electronic system of speed sensing and control. A hydraulic system is used to amplify the controller's signals and generally is replaced when the controller is replaced. The main valve supplied by the hydraulic system may, or may not be replaced in an upgrade scenario depending upon its condition and the economics of its replacement.

Modern governors tend to use high pressure hydraulic systems (>800 psi) as opposed to the low pressure systems of the past. Consequently they have a reduced volume of oil and have better response. New servomotors have also improved response characteristics.

A digital governor can perform many additional functions not previously provided by mechanical governors and some not provided by analogue governors. It can control any system parameter that can be sensed by a transducer, switches or contacts.[30] Examples include:

- Speed and power control.
- Generator control - can include voltage and VAR control.
- Pond control - for head or tailwater control.
- Flow control - for minimum flows
- Turbine creep detection.
- Control sequencing - can expand sequencing capabilities and allows ease of changes for such applications as sequencing of multiple units or unit start or stop based on time to control ponding, irrigation, or scenic water flow requirements.
- Unit remote control - can remotely start, stop and change set points and governor parameters along with sending warnings and log data by communications link.
- Loading Optimization Schemes - Software can be written to maintain higher efficiency regions of the unit operating range and avoid rough zones of operation. Turbine data can be programmed into the governor to make automatic adjustments to avoid cavitation.
- Dual-Regulated Turbine Optimization - For Kaplan and Pelton turbines, there are optimum regulation requirements for the secondary control servo. For Kaplan turbines, gross head and gate positions are used as inputs to the control to determine optimum blade position. For Pelton turbines, increased efficiency can be gained with needle sequencing. For example, at a half-rated capacity, a six-needle machine has a higher efficiency with three needles in service that with six.[31]

The main advantage of a digital governor is its versatility and its ease of upgrading and interfacing with other computers and control systems.

A.2.3 Wicket Gates and Stay Vanes

Wicket gate replacement or modification is normally considered in conjunction with runner replacement, through the use of CFD techniques, to add further efficiency gains to the modernization process. To achieve these gains new wicket gates and stay vanes are built:

- slimmer
- more aerodynamic
- having a better angle of approach
- to suit ‘actual’ head conditions

[30] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 4-11, 1996.

[31] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 4-11,12 1996.

As an alternative to wicket gate and stay vane replacement, on site modification is often considered. Reshaping the gates and vanes to shapes recommended by CFD can be carried out on site with water jet cutting and/or grinding being used to complete the work.

Another development in the area of stay vanes is the use of polymers for the repair of cavitation damage.[32]

A.2.4 Draft Tubes

Draft tubes have occasionally been modified to gain efficiency improvements brought about by decreased head losses. CFD and hydraulic model tests have also assisted with the improved design.

Venting rings in draft tubes are also being used to improve dissolved oxygen levels in flows.

A.2.5 Self Lubricated Bushings

The drivers for the use of self lubricated bushings are:

- Improved environmental performance
- Decreased maintenance costs
- Reduced capital costs

In the past, a possible source of hydrocarbon contamination has been grease leakage from wicket gate bushings. The self lubricating bushing is now used to replace the classical bronze wicket gate bushing as no greasing is necessary helping to improve environmental performance.[33]

Two main categories of self lubricating bushings exist: polytetrafluoroethylene (PTFE) fluorocarbon and carbon bronze.[34] PTFE bushings are water lubricated and are inserted into a sleeve for support. Carbon bronze bushings either use circular inserts of carbon into the bronze bushing or impregnate carbon particles into the molten bronze during casting.

Self lubricated bushings are less expensive than the traditional bronze bushing and have lower maintenance costs.

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[32] Moss W.O., Morton R., "The Successful Solution to Cavitation Problems at Dinorwig Power Plant with the aid of Polymeric Coatings" Uprating and Refurbishing Hydro Powerplants V Conference Proceedings Vol. 3 1995.

[33] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.

[34] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.

A.2.6 Turbine Bearings

Water Lubricated

Smaller turbines are now able to use water lubricated turbine guide bearings, in lieu of oil lubrication, to eliminate another source of hydrocarbon contamination.[35] Costs are comparable to, even lower, than using conventional oil lubricated guide bearings.

PTFE Bearings

Turbine bearings are now using PTFE coated pads in lieu of white metal coated pads. The PTFE offers several advantages over white metal:

- It has three times the load capacity of white metal bearings.
- It is tolerant of load and thermal transients.
- It eliminates the need for high pressure oil at start-up.
- It allows pad surface area to be reduced, reducing power loss by 30%.
- It offers an insulated system, eliminating circulating currents, when used in journal pads.[36]

Like for like, PTFE bearings cost approximately 20% more than white metal but there are associated savings due to the smaller size of the bearing and the lack of the oil injection system.

A.2.7 Condition Monitoring

The drivers for the use of predictive maintenance and condition monitoring have been the requirements for:

- Increased reliability
- Increased intervals between outages
- Decreased outage durations

Predictive maintenance involves the collection and interpretation of operational data to predict maintenance requirements.

The aim of using predictive maintenance is to attempt to extend maintenance intervals beyond the existing, time-based preventative maintenance periods. Predictive maintenance also seeks to identify and rectify problems before they become catastrophic which may not have been possible by relying on preventative maintenance techniques.

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[35] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.

[36] Anon., "PTFE bearings offer reliability at Dinorwig" in *International Water Power and Dam Construction* Vol. 50 No. 8 August 1998 p. 41.

Condition monitoring is used to provide a more comprehensive predictive maintenance program. It collects performance data, either continuously or periodically, such as vibration, temperature, flow rates, power usage and oil quality. This data, at present, is interpreted “off-line” to attempt to predict maintenance requirements. Many attempts are underway to use condition monitoring systems “on-line” which will continuously monitor parameters and provide “smart” alarms which are more predictive than the present alarms used which simply alert the operator that a set point has been reached which does not allow for outside parameters.

An example of the use of a “smart” system condition monitoring would be an alarm which alerts the operator to a problem with a turbine guide bearing temperature at half load which is not critical, in terms of maximum allowable bearing temperature, at that juncture, but which is an indicator of a problem occurring. By identifying the problem at an earlier point, there is the opportunity to investigate and perhaps fix the problem at a more convenient opportunity than with the problem being identified at full load and at an inconvenient moment when a forced outage is not desirable.

A problem with implementing condition monitoring in a hydro plant situation is that the plant has very slow wear rates. Changes in performance, which provide the trends that condition monitoring relies upon, are very gradual, i.e. over many years and trending of these parameters needs to take account of this.

A.3 Electromechanical

A.3.1 Generator

Improvements in generator technology have been urged by the following drivers:

- The general requirement for increased power output/capacity at higher unit efficiencies.
- Reducing outage frequency and duration.
- Lowering maintenance/overhead costs.
- Simplifying the process (i.e. eliminating unnecessary plant items).
- Improving worker safety.

The improvements have been achieved by:

- Better insulation materials which require less space and allow more copper to be installed per unit volume with subsequent higher power output for unit volume.
- Better testing and monitoring techniques which allows improved operating techniques.
- Innovative construction/overhaul methods.
- Eliminating the requirement for items such as the generator transformer and associated switching equipment.
- When possible switching from multi-turn lap windings to single turn wave windings, which will eliminate dangerous turn to turn failures and ease relaying.

Design

The ability to eliminate the generator transformer and associated equipment has recently been developed. The recent construction in Sweden of a generator known as Powerformer™ with high voltage output has eliminated the need for a generator transformer and associated equipment. The concept has been developed by Asea Brown Boveri (ABB) and has efficiency benefits along with risk reduction benefits by the omission of the generator transformer and associated equipment. The generator has the potential to generate at voltages between 20 and 400 kV.[37] The improvement is achieved with the use of round high voltage cables as conductors in the stator in lieu of the traditional square conductors and has benefits of no partial discharges and, due to its robust design, can be overloaded for long periods which assists during system disturbances.[38] The Powerformer™ is still in the development phase but its first commercial order has been received (from a thermal plant in Sweden).

Materials

Generator output can be improved by the use of thermo-setting materials as insulating mediums. The new materials allow more copper to be inserted into the generator during the rewind process. This is achieved because the same level of insulation performance can be achieved with smaller quantities of thermo-setting plastic insulation which allows more copper to be accommodated in the original generator 'volume'. An automatic uprating of between 15 and 25%[39] can be expected from a rewind using modern insulation.

Better heat transfer characteristics[40] are also a benefit of using modern insulating materials.

Thermo-setting coil and bar coatings are also being used in place of conventional side packings for windings to improve performance.

The use of low loss cores utilizing grain oriented silicon steels is also a feature of modern generators.

In the future, superconductors may further improve the capabilities of generators but more research is required in this area.

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[37] Isaksson K. and Karlsson T., "Technology for the Future: Development of a New Generator" in *Hydro Review Worldwide* May 1998.

[38] Magnell L., (1998) "Reactive power compensation" in *The voltage: the story behind the high voltage generator from ABB*, p5. ABB Generation AB: Västeräs, Sweden. Supplement to *Hydro Review Worldwide* Vol. 6, No. 4, September 1998, 11p.

[39] Gummer B., Barr D., Sims G., "Evaluation Criteria for Upgrading Hydro Powerplant" in *Water Power and Dam Construction* December 1993.

[40] Whiteoak N. and Jeannez P., "Hydroelectric Generators: Repair or Refurbishment?" in *GEC Review* Vol. 12, No. 1, 1997.

Operation

Modern practice is now to operate generators at the full temperature limit of their insulation system,[41] typically Class F instead of Class B, allowing increased generator output. Efficiency improvements are, on average, 1.5% for the stator and 1.5% for the rotor.

With the advent of on-line condition monitoring, the ability to monitor and trend operational parameters has improved significantly, allowing the generator to be operated at nearer its actual capability limits rather than its nameplate rating.

Innovative Construction Methods During Modernization

Innovative construction techniques have been designed to minimize downtime and revenue loss. The cost of lost generation revenue is a factor in the costing of the modernization process and minimizing this loss of revenue makes the modernization economics more attractive. An example is the USBR's Grand Coulee Plant where the replacement stator was constructed outside the unit to be modernized, as opposed to the traditional method of building the stator in situ, and placed into position as a complete unit. This helped to reduce the outage time from one year to 70 days with a significant reduction in revenue loss.[42]

Modernization projects for generators have also benefited from process improvements such as induction brazing which has produced high quality results, reduced costs and production times[43] resulting in an improved product.

A.3.2 Excitation and Voltage Regulation

Exciter upgrades are often initiated because of the:

- Lack of spare parts for the existing exciters (obsolescence)
- Automation of the hydro plant requiring it (modernization)
- Requirement to improve plant performance characteristics

Exciter technology has embraced the use of static exciters, which first appeared in the 1960s, over rotary exciters. The first static exciters used mercury arc rectifiers to convert AC to DC but modern design uses solid state circuitry.

In most cases, rotary exciters, because of their age, tend not to be supported by manufacturers and spare parts are difficult to find which forces their replacement. Static exciters have the benefit of higher efficiencies than rotary exciters. The improved performance of static, electronic

[41] Whiteoak N. and Jeannez P., "Hydroelectric Generators: Repair or Refurbishment?" in *GEC Review* Vol. 12, No. 1, 1997.
[42] Light S. and White, E., "Grand Stator Affairs" in *Waterpower and Dam Construction*, April 1997.
[43] Light S. and White, E., "Grand Stator Affairs" in *Waterpower and Dam Construction*, April 1997.

(analogue or digital) excitation system, in conjunction with the voltage regulation system, can widen the output range or improve the response time of the unit[44] which may increase the plant's value to the system it supplies.

Digital excitation is a development on the analogue electronic excitation system and can provide more features than its analogue counterpart. The digital systems are drift free[45] which is an improvement on the analogue excitation system in which gains and time constants tend to drift over time.

Where improved response is not of value to the system, a more cost effective upgrade, in lieu of a full static excitation system, may involve the installation of a static pilot exciter in conjunction with the existing rotary exciter.[46] The static pilot exciter replaces the existing voltage regulator but continues to use the main rotary exciter.

Where rotary exciters remain in use, brushgear has moved towards the use of constant pressure brush holders as an upgrading measure.

Voltage regulation improvements have centred on digital control improvements in line with excitation improvements. The modern automatic voltage regulator (AVR) is digitized and a key component of the modern excitation system.[47] The digital AVR can be quicker and easier to troubleshoot and maintain as digital AVRs, unlike their analogue ancestors, do not require additional hardware for each additional function they perform. The additional functions are incorporated into the software of the digital AVR meaning there is less hardware to break down.[48]

A.3.3 Synchronizer

Automatic synchronization has become widely used with the developments in control systems and the automation of hydro plants. It can be integrated into a digital governor, a digital AVR[49] or be incorporated in an independent programmable logic controller (PLC).

Individual unit synchronization is now the preferred synchronization method as opposed to the plant synchronization method using a bus system of earlier times.

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[44] Whiteoak N. and Jeannez P., "Hydroelectric Generators: Repair or Refurbishment?" in *GEC Review* Vol. 12, No. 1, 1997.

[45] Hajagos L.M., Bérubé G.R., "Utility Experience With Digital Excitation Systems" IEEE Transactions on Power Systems, Vol. 13, No. 1, February 1998.

[46] Wilkinson G.M., "Static Pilot Exciters - An Alternative at One Fifth the Cost" Electricity '94 Conference Proceedings.

[47] Hopf D., "Upgrading the Excitation System, one step towards ultimate station reliability" Uprating and Refurbishing Hydro Powerplants V Conference Proceedings Vol. 3 1995.

[48] Hopf D., "Upgrading the Excitation System, one step towards ultimate station reliability" Uprating and Refurbishing Hydro Powerplants V Conference Proceedings Vol. 3 1995.

[49] Hopf D., "Upgrading the Excitation System, one step towards ultimate station reliability" Uprating and Refurbishing Hydro Powerplants V Conference Proceedings Vol. 3 1995.

A.3.4 Condition Monitoring

As previously discussed in Section A.2.7, the drivers for the use of predictive maintenance and condition monitoring have been the requirements for:

- Increased reliability
- Increased intervals between outages
- Decreased outage durations

Condition monitoring is used for generators to attempt to extend the life expectancy of the equipment by avoiding catastrophic failure and reduce maintenance costs. Methods of monitoring 'on-line' generator parameters include:

- Measurement of ozone levels in air cooled generators to indicate faults in generator windings, insulation and brushgear systems. A relatively high concentration of ozone in these areas is a good indicator of problems.[50]
- Measurement of the air gap between rotor and stator to indicate the shape of rotor and stator, minimum and maximum air gaps around the generator and the roundness and eccentricity of the rotor and stator.[51] This information can provide data concerning the condition of the generator, but also about any concrete growth that may be occurring, and help to avoid catastrophic failure.
- Measurement of vibration of stator core which can provide information on the clamping system between the core and frame.
- Infrared thermal imaging of stator provides comprehensive temperature monitoring of the entire stator.
- Monitoring of bolt vibration which can provide a large amount of data on the mechanical system but which is difficult to turn into useful information.
- Measurement of insulation degradation using a permanent coupler connected direct to the stator winding. This method is known as partial discharge analysis.
- Measurement of wave form discontinuity using a direct axis Hall effect probe to check the integrity of each coil to detect a set of shorted turns or strands.
- End turn capacitive test to detect water leakage in water cooled machines.

[50] Franklin D.E., Cartlidge D.M., Casson D.W., Macdonald J.A., "Development of an On-Line Ozone Monitoring System for Air Cooled Generators" Electricity '94 Conference Proceedings.

[51] Major C., Allen G., Houle Y., "Monitoring the air gap" in *International Water Power and Dam Construction* Vol. 49, No. 7, July 1997.

A.4 Auxiliary Mechanical

A.4.1 Air Compressors

Due to the wide range of individual requirements for each plant, technology advances in air compressors will not be discussed here and are best discussed with manufacturers. The use of compressed air, however, will be discussed.

Air compressors are being used to assist with mitigating the effects of hydro plant operation on water quality in the areas of temperature and dissolved oxygen. Temperature concerns can be reduced with air compressors by using air injection to destratify reservoirs. Dissolved oxygen levels can be addressed during the same destratification process and by directly injecting air into the flow passage of turbine.

Air injection is also being used to minimize "rough zones" encountered during turbine operation. Air can be admitted at the top of the draft tube, behind the runner band, at the bottom of the runner crown or at the bottom of the runner cone[52] to diminish pulsations caused by vortex cores. Efficiency can be improved by as much as 1% at the operating point[53]. Careful use needs to made of air injection as, if used when not needed, efficiency may be decreased by as much as 4%.[54]

A.4.2 Cranes

Technology advancements in typical applications for cranes in hydro plant situations have been limited mainly to improved control systems which assist with the ease and accuracy of the crane's operation. The use of AC drives in lieu of DC drives is also a popular advance. Variable speed AC drives, in particular, are the popular modern alternative for their controllability.

A.4.3 Emergency Generator

Due to the wide range of individual requirements for each plant, technology advances in emergency generators will not be discussed here and are best discussed with manufacturers. The focus of any replacement emergency generator task is the sizing and reliability of the replacement unit. Emergency power requirements have tended to increase over time with the change in control systems and an important part of any modernization process is to ensure that emergency power requirements are adequately covered. Reliability is vital due to the emergency purpose of the generator.

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[52] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 3-45, 1996.

[53] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 3-45, 1996.

[54] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 3-45, 1996.

A.4.4 Fire Protection

Improvements in fire protection techniques have been driven by:

- The need to avoid "false alarm" fire system operation and its subsequent effects.
- The need to detect and deal with fires at the earliest possible moment to minimize equipment damage and life safety risk.
- The need to consider life safety and environmental aspects of extinguishing mediums being used (e.g. halon and CO_2).

In response to the drivers, fire protection technology has developed in the following ways:

- A probabilistic approach is now being used to enable a methodical and thorough assessment of fire risks.
- A deterministic approach is also being used in assessing fire risk with computer-based modelling being used to simulate fires and predict fire conditions.
- Fire detection methods have become computer based with algorithms being used to ignore incidental events such as "burnt toast" in the operators' meal room. Addressable fire protection devices which can be interrogated have also been developed.
- Fire detection using air sampling has also been developed providing early warning of fires. Fires may be detected in the arcing stage as opposed to the flame stage.
- Fire extinguishing methods have moved away from carbon dioxide and halon due to life safety and environmental concerns. Water based extinguishing has come to the fore, especially with the use of water mists. Inert gases such as Inergen™, which act to reduce oxygen content in the atmosphere surrounding the fire to a level below that which supports combustion whilst still allowing persons in the area to breathe, are also being used.

A.4.5 Heating, Ventilation and Air Conditioning (HVAC)

The driver to improve HVAC performance has been the requirement to improve net power output from the hydro plant. Previously, the control technology was not available to optimize HVAC performance with the consequent waste of power. Digital control systems have allowed the optimization of HVAC performance.

The heating, ventilation and air conditioning requirements for a hydro plant are very similar to that of a large industrial building, except that, in some cases, special requirements will exist for underground construction or the large heat loads that may be imposed by electrical equipment.[55] Any modernization of a hydro plant should at least include a review of the HVAC at the plant and its ability to meet the loads imposed by the modernized plant and the requirements of present day codes.

[55] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 9-30, 1996.

The development of improved control systems for HVAC is the main area of interest for new technology in the area which will assist in the improved efficiency of the plant. The control systems:

- Are computer based (can be PC Windows-based).
- Provide real time information about the operation of the system which allows optimization of the HVAC system resulting in substantial reductions in operating costs.
- Allow troubleshooting by 'informed', instead of expert, personnel;
- Use graphics based displays for ease of operation.

Variable speed drives used for fans, etc. have allowed the improved control systems to operate HVAC systems much more accurately with the benefits of improved efficiencies.

A.4.6 Environment

The drivers for improved environmental performance, along with a discussion, are set out in Section 2.3.3 of Volume 1.

Environmental issues addressed by the use of auxiliary mechanical equipment include water quality effects such as temperature, dissolved oxygen and contamination.

Temperature

Reservoir destratification may be achieved by using water circulating pumps.[56]

Dissolved Oxygen

Mechanical aerators are occasionally used to introduce higher dissolved oxygen level.[57] Fixed cone dispersion valves are also used for this purpose.[58]

[56] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-20, 1996.
[57] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.
[58] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23 to 10-25, 1996.

Contaminants

Methods to reduce petroleum contamination include:

- Oil separators.
- Double walled heat exchangers.
- Non-petroleum based lubricants.
- Water hydraulic systems and the use of "environmentally friendly" hydraulic fluids.[59]

A.5 Auxiliary Electrical

A.5.1 Generator Transformer

Technology development in generator transformers has occurred in the following areas:

- Efficiency improvements have centered on decreasing losses using low loss steel for cores and laser cutting and edging of the steel to produce a more uniform core profile. Losses have decreased in the order of 50%.
- Resin and fibreglass bushings are being used in lieu of porcelain bushings.
- Continuous condition monitoring is being used to evaluate performance and maintenance requirements. Parameters being monitored include dissolved gas in oil, rate of temperature change and even noise levels. An example of this is the Transformer Performance Analysis (TPAS) project which is attempting to predict imminent transformer failure.
- Auxiliary coolers are also being fitted to generator transformers to allow an uprating to cope with generator uprates.

Research is continuing into the use of high temperature superconductors (HTS) in transformers but no commercial operation has occurred to date.

A.5.2 Station Service and Auxiliary Transformers

Developments in the area of station service and auxiliary transformers have centered on the use on 'dry' transformers to mitigate fire and environment risks. The efficiency improvements mentioned above for generator transformers also apply here.

A.5.3 AC Systems

Switchgear in AC Systems has developed to be higher rated, faster, more compact than their predecessors.

[59] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.

A.5.4 DC Systems

The main development in DC systems has been in the area of batteries:

- modern batteries have reduced maintenance requirements and slightly longer lives. (Some examples of Ni-Cad batteries are in use but the most popular are still the lead acid types.)
- automated monitoring of individual cell systems (reduces staff time to monitor and log battery condition).

A.6 Site and Civil Works

A.6.1 Dams

Improvements in dam related technologies have been urged by the following drivers:

- Understanding the ageing of dams and how to extend their lives.
- Understanding, detecting and preventing piping and internal erosion of embankment dams.
- Understanding and dealing with concrete dam cracking, Alkali-Aggregate Reaction (AAR) and frost damage.
- Understanding the behaviour of materials (compacted earthfill in dams).
- Understanding the behaviour of dams in extreme events such as earthquakes and floods.
- The increase in earthquake loadings and probable maximum flood levels and how to strengthen dams.

The technological advances that have occurred in response to the drivers have been:

- Finite element methods (FEA/FEM) being used in the analysis of dams and the understanding of dam behaviour.
- An enhanced understanding of flood hydrology leading to more rational procedures for design flood estimation.
- An improved understanding of the nature and behaviour of compacted earthfill in dams (including hydraulic fracture and the erosion characteristics of fill).
- The development and utilisation of advanced ground engineering and grouting procedures.
- Improved understanding of seismicity and of the seismic response of dams.
- Enhanced monitoring and surveillance capability achieved through improved reliable instrumentation and the development of associated assessment procedures.[60]
- Infrared investigative methods intrusive and non-intrusive.
- Development of AAR repair and monitoring techniques.
- Development of membranes/geotextiles for erosion control (internal and external).

[60] Moffat A.I.B., "A good report for research?" in *International Water Power and Dam Construction* Vol. 50 No. 8 August 1998 p. 39.

Dam Safety

Using the developments above a major change in the focus of dam safety has been the realization that dam monitoring, which takes place during construction and initial reservoir filling, should be continued during the life of the dam. In the past the monitoring equipment tended to be abandoned at the completion of the initial reservoir filling.

Dam Repair Techniques

The repair of aging dams is an important consideration for the life extension and modernization of hydroelectric facilities. Some typical problems, with their associated repair techniques, are:

Alkali-Aggregate Reaction (AAR)

AAR is a contributing factor for concrete growth, deterioration and distress. It is a chemical reaction in concrete which occurs when alkali in the cement reacts with certain silicate or carbonate minerals in the aggregate. This chemical reaction results in a gel which absorbs moisture and swells.[61]

Concrete structures experiencing AAR generally demonstrate some of the following characteristics:

- Spillway and other openings may show closure or tilting, resulting in binding of spillway, intake and lock gates.
- Dams may experience tension cracking in the upper portion due to the differential growth rate between the downstream face and the interior of the dam.
- Plumbline readings for a dam may indicate an upstream movement.
- Expansion and contraction joints can permanently close.[62]

Before a management plan can be developed, data regarding the effect of AAR on the dam in question must be gathered. It generally takes at least three annual seasons before trends from AAR growth can be separated from annual thermal changes in massive concrete structures.[63]

Finite Element Modeling (FEM) has allowed cost-effective development of detailed models which can simulate the behaviour and performance of AAR in structures. The models can also be used to evaluate alternatives that can be used to mitigate the effect of AAR.[64]

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[61] Wagner C.D., Meisenheimer J.K., “Developing a Management Plan for Alkali-Aggregate Reaction in Dams” Waterpower ’97 Conference Proceedings Vol. 1 P274.

[62] Wagner C.D., Meisenheimer J.K., “Developing a Management Plan for Alkali-Aggregate Reaction in Dams” Waterpower ’97 Conference Proceedings Vol. 1 P276.

[63] Wagner C.D., Meisenheimer J.K., “Developing a Management Plan for Alkali-Aggregate Reaction in Dams” Waterpower ’97 Conference Proceedings Vol. 1 P277.

[64] Wagner C.D., Meisenheimer J.K., “Developing a Management Plan for Alkali-Aggregate Reaction in Dams” Waterpower ’97 Conference Proceedings Vol. 1 P277.

The repair techniques for AAR include:

- The use of stress relief slots by slot cutting to allow room for the concrete structure room to 'grow'.
- Shear control by the use of post-tensioned anchors.

FEM can be used in conjunction with these repair techniques to predict requirements for future slot cutting maintenance, additional slot locations and estimated time requirements for installation and loading increases in anchor systems.[65]

Dam Leakage

Dam leakage mostly occurs through cracked or deteriorated concrete and defective joints. Conventional repair techniques generally consist of localized sealing of cracks and defective joints by cementitious and chemical grouting, epoxy injection, or surface treatments.[66]

Geomembranes are also used for dam repairs. They have been used as synthetic barriers in dams for more than 30 years. In recent years, they have also been used for seepage control and have been used to successfully resurface the upstream face of old concrete and masonry dams, particularly in Europe. Mostly, however, the installation of geomembranes has taken place in dry situations requiring dewatering which can be expensive and not always possible with project constraints. A technique has now been developed for the installation of geomembranes for underwater repairs.[67]

Risk Assessment

Risk assessment techniques with regard to civil works have developed with the increased understanding of the impact of events such as earthquakes and floods. The better understanding of these events allows mitigation works to be better formalized and focused (Refer to Sections 2.3.2 and 4.4).

A.6.2 Structural Soil and Drainage Systems

The importance of maintaining and restoring drainage systems has been highlighted in recent years and an increased importance has been placed on the activity.

[65] Wagner C.D., Meisenheimer J.K., "Developing a Management Plan for Alkali-Aggregate Reaction in Dams" Waterpower '97 Conference Proceedings Vol. 1 P279.

[66] McDonald J.E., Scuero A.M., Marcy M.A., "Geomembrane Systems for Underwater Repair of Dams" Waterpower '97 Conference Proceedings Vol. 1 P175.

[67] McDonald J.E., Scuero A.M., Marcy M.A., "Geomembrane Systems for Underwater Repair of Dams" Waterpower '97 Conference Proceedings Vol. 1 P175.

A.6.3 Penstocks and Trashracks

Penstocks

Improvements in penstocks have been urged by the requirement to enhance hydraulic performance by reducing head loss. This is being achieved by:

- The use of new internal coatings, but the method of application must be exact for long-term performance.
- Design optimization of penstocks sizing if the penstock is being replaced.

Life extension is also driving improvements in penstock surveillance and testing with surveillance techniques being upgrade to optimize the life of internal and external protective coatings.

Ductile iron pipe is also being used as a penstock material as it is now available in larger pipe diameters.[68]

Penstocks are also being used to assist with dissolved oxygen levels using:

- Direct injection of liquid oxygen
- Inlet aspiration systems[69]

Trashracks

Trash rack advances have centered around the requirement to maintain unimpeded flow and minimized head losses. Innovative cleaning methods with improved cleaning appliances now tend to be hydraulically driven and automated to the extent that they operate automatically when required in the clogged area of the trash rack. The design of trashracks has moved away from flat rack bars to hydrodynamically shaped bars which have lower head loss, are less affected by vibration and are more easily cleaned.

A.6.4 Buildings and Structures

The major advance in building and structures has been the allowance for dynamic loads in design procedures. This has been in response to seismic design requirements. The improved computing capabilities of today have allowed more detailed design analysis to be undertaken.

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[68] Hurless R.C., "Using Ductile Iron Pipe for Penstocks: A New Option" in *Hydro Review* Vol. XV, No. 2, April 1996.

[69] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-20, p. 10-22, 1996.

A.6.5 Environment

Several areas of environmental performance have been addressed in recent times with innovative solutions being developed.

Fish Protection Systems

Fish protection systems have been developed to mitigate the effect of hydroelectric generation. The major systems in use, or being tested, include:

- Fish ladders for upstream migration
- Fish elevators and locks for upstream migration
- Fish bypass systems for downstream migration
- Fish pumps for downstream migration
- Travelling screens for downstream migration
- Fish screens for downstream migration[70]

Water Quality Enhancement Systems

Water quality enhancement systems from the site and civil works perspective include:

- Multilevel intake structures to mitigate the effects of temperature and dissolved oxygen.[71]
- Spilling weirs to assist with dissolved oxygen levels.[72]
- Adjusting spillway design to reduce gas supersaturation.[73]

A.7 Protection and Controls

Improvements in protection and control systems have been driven by the:

- Need for increased reliability
- Need to improve the plant operational characteristics
- Need to reduce operating costs

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[70] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-9, 1996.
[71] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-20, 1996.
[72] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.
[73] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-7, 1996.

Control systems have developed through:

- Full manual, to
- Electro-mechanical, to
- Electronic components - analogue based, to
- Full digital

With the advent of digital controls the trend has been to move from a central plant control room to decentralizing the controls - moving them out to the field. The control devices can be linked as part of a LAN or WAN system.

An advantage of decentralizing controls has been the reduction in cabling which as reduced:

- Expense
- Manpower
- Risk (fire, etc.)
- Space requirements (important for rehabilitation work)

The use of fibre optics has also eliminated EMF transfers and fault potentials and allowed communications and control to be conducted together.

PLC controllers have improved greatly, in terms of reliability, to such an extent that manual systems do not now need to be paralleled with them (there is resistance to this line of thought). Redundancies in the form of power supplies, processors etc. can be built into the PLC to cover concerns.

Multifunction digital relays have come an ideal and cost-effective way to upgrade protection. They are compact (space generally being a concern in a hydroelectric modernization situation) and can easily be set up for remote communication and operation.[74]

The functions that are now built into digital controllers as standard items have meant that the previously separate areas of protection and controls are being interwoven. For example, the control system has the ability to collect and process so much information that it can provide protection also. In a similar way it is possible to use protection relays as a defacto control system.

The improvements that are continually being generated in controls can also be easily added to the installed control system. Costs have also fallen dramatically.

[74] ASME Hydro Power Technical Committee, *The Guide to Hydropower Mechanical Design* HCI Publications p. 10-23, 1996.

Control system designs have also been developed to improve environment performance along with operational performance. Characteristics include:

- Sensing fish presence at each turbine and limit turbine operation to "fish friendly" modes when fish are present.
- Automatically adjusting Kaplan blades to the most efficient operation at each head and flow to optimize operations and minimize fish injury from turbulent flows.
- Sensing cavitation and limiting operation to non-cavitating conditions.
- Optimizing plant output when fish are present to achieve targeted fish passage survival.[75]

[75] Fisher R.K., March P.A., Mathur D., Sotiropoulos F., Franke G., *Innovative Environmental Technologies Brighten Hydro's Future* presented at Hydrovision '98, Reno, Nevada, August 1998.

B
APPENDIX B: BACKGROUND TO MODERNIZATION OPPORTUNITIES

B.1 Introduction

This appendix contains background information on Modernization Opportunities that can enhance the product portfolio of a Hydro Plant.

In Screening and Prioritization (Section 3), the performance of each hydro plant is rated against a set of indicators to assess opportunities for modernization. The indicators used are: Output and Flexibility.

During development of the Life Extension and Modernization Plans (Section 4), potential plant improvements are identified. These are based on the existing level of service and an assessment of opportunities to improve this level of service for that plant as well as all other plants within an owner's portfolio.

Modernization opportunities are classified under the following categories:

- energy
- portfolio services
- ancillary transmission services
- flexible operation
- automation
- other services

This Appendix describes the possible opportunities for improvement. Possible ways to achieve improvements in each of the categories are noted, as well as the potential benefits. Each method is cross-referenced to specific areas of the technical guides.

B.2 Energy

Opportunities to increase energy output from plants (Table B-1) are shown below:

Table B-1
Opportunities to Increase Energy Output from Hydro Plants

PRODUCT AND SERVICES		UNITS	WAYS TO ACHIEVE INCREASE	POSSIBLE BENEFITS	REFERENCE TO TECHNICAL GUIDES
Energy	High Load Hours	GWh	• Increased efficiency of hydromechanical equipment (upgrade) • Increased automation	Increased output	
	Low Load Hours	GWh	Increased efficiency of electromechanical equipment	Increased output	
			Operational improvements • stop start • change in unit operation • reduction in environmental releases • improved reservoir management (reduced spillage)	Improved dispatch Increased output	
			Changes in duration and timing of maintenance	Increased availability	
			Additional diversions into reservoir	More water	
			Reduction in hydraulic losses including leakage • intakes (including trashracks) • conduits, canals, tunnels • penstocks • units • draft tubes		
			Increases in head • reduce freeboard allowance • reduce drawdown level • add flashboards • raise dam • lower tailwater level	More energy and capacity	
			Heating and ventilation improvements	Lower station load	
			Cooling water improvements	More water available	

Examples of increasing energy output in an economic manner can be found in the Annotated Bibliography to this volume, as well as Volumes 2 and 3.

B.3 Portfolio Services

Table B-2
Product Portfolio Improvements

PRODUCT AND SERVICES		UNITS	WAYS TO ACHIEVE INCREASE	POSSIBLE BENEFITS	REFERENCE TO TECHNICAL GUIDES
Capacity[1]	Firm Capacity	MW	Increased capacity of hydromechanical equipment (uprate)		
	High Load Hours	MW	Increased capacity of electro-mechanical equipment Increased storage to move generation to high load hours		
	Low Load Hours	MW	Increases in hydraulic head • reduce freeboard allowance • reduce drawdown level • add flashboards • raise dam • lower tailwater level Changes in unit rating Operation above unit rating (overgating)		
Storage[2]			Increases in reservoir level Increase storage volume Use other lakes		
River System Regulation[3]			Changes in rule curve operation Improved system operation between all plants on river		
Water Management[4]					

Table B-2 - Notes:

1. Reliable capacity is the maximum sustainable amount of power that can be produced at any point in time. Increased capacity above rating of the units, i.e. overgating, is included.

2. Storage is the ability to retain water behind an impoundment. Live storage is the volume of water that can be used. Water is stored:

- to allow other plants with little storage to avoid spill.
- to collect water in high run-off periods for use at low run-off times.
- to balance water use with other catchments.
- to optimize fuel use by storing water when other fuel is available and at low prices.

3. River System Regulation is the ability to balance the use of water between plants in a cascade. This includes storage, operating rule optimization and dispatch.

4. Water Management covers the use of the water resource and in particular:

- modification to reservoir rule curves to increase water and head available for generation.
- regulation of reservoir discharges to minimize variations in long-term energy production and shifting water availability to periods of highest value.
- operation of generating equipment as close to peak efficiency as possible.

Examples of increasing portfolio services in an economic manner can be found in the Annotated Bibliography attached to this volume as well as Volumes 2 and 3.

B.4 Ancillary Transmission Services

Opportunities to increase Ancillary Transmission Services from plants are shown in Table B-3.

Table B-3
Opportunities to Increase Ancillary Transmission Services from Hydro Plant

PRODUCT AND SERVICES	UNITS	WAYS TO ACHIEVE INCREASE	POSSIBLE BENEFITS	REFERENCE TO TECHNICAL GUIDES
Voltage Support[1]	hrs/yr	Digital exciter and automatic voltage regulation (AVR)	Value of service	
Synchronous Condenser[2]	MVar.hrs	Tailwater depression	Value of service	
Black Start[3]	n/yr	Install generator/batteries	Value of service	
Local Load[4]	% of installed capacity	Low Voltage take off	Reduced transmission costs	

Table B-3 - Notes:

1. Voltage Support is operating at high or low voltage to lift or lower voltage at the customer end of the line.

2. Synchronous Condenser is operation at a power factor of more or less than unity to accommodate the losses caused by reactive loads and long lines. The product is created either during normal operation by dropping some load to accommodate extra heating or through synchronous condense operation.

3. Black Start is the ability to start up plant when not connected to the transmission system. Requires dedicated power source for ancillary equipment and ability to create own field in exciter. Only required in areas which may become isolated.

4. Local Load - If a plant has a local load nearby it can supply without incurring transmission losses or needing voltage support, therefore this is a supplement to a plant. Measured as a percentage of installed capacity. Intended primarily for remote plants.

Examples of increasing Ancillary Transmission Services in an economic manner can be found in the Annotated Bibliography attached to this volume as well as to Volumes 3, 5 and 7.

B.5 Flexible Operation

Opportunities to increase Flexible Operation from plants (Table B-4) are shown below:

Table B-4
Opportunities to Increase Flexible Operation from Plants

PRODUCT AND SERVICES	UNITS	WAYS TO ACHIEVE INCREASE	POSSIBLE BENEFITS	REFERENCE TO TECHNICAL GUIDES
Base Load[1]	hrs/yr	Stop start capability and improved unit dispatch can provide increased energy output		
Load Factoring[2]	hrs/yr	Digital governor		
Swing[3]	hrs/yr			
Automated Generation Control (AGC)[4]	hrs/yr			

Table B-4 - Notes:

1. Base Load is inflexible plant operation regardless of system demand, usually to avoid spill, provide spinning reserve and because units may not have remote stop start capability.

2. Load Factoring is usually a daily mode of operation where units have two different load setting for heavy load hours and light load hours.

3. Swing Operation has output varied in steps every ½ hour to adjust system output to keep AGC plants in mid range.

4. AGC operation (or frequency keeping) has output varying continually to match demand. This mode is the most flexible operation and hence potentially the most valuable.

Examples of increasing flexible operation in an economic manner can be found in the Annotated Bibliography to this volume as well as Volumes 2, 3 and 6.

B.6 Automation

Opportunities to increase automation of hydro plants are shown on Table B-5.

Table B-5
Opportunities to Increase Automation from Hydro Plants

PRODUCT AND SERVICES	UNITS	WAYS TO ACHIEVE INCREASE	POSSIBLE BENEFITS	REFERENCE TO TECHNICAL GUIDES
Full Automation[1] **Partial Automation**[2] **Unstaffed Operation**[3]		Benefits of the various levels of automation include: • better water management, allowing optimization of generation from available water • better unit protection, minimizing damage if fault occurs • lower operating losses in powerplant • some reductions in staff requirements (automation is rarely justified on this benefit alone).		

Table B-5 - Notes:

1. Full automation is the provision of equipment and components necessary for remote control and protection of a generating unit. This will enable to operator to:

- start the unit and synchronize automatically to line
- load the unit and control the selected values of watts and vars
- optimize the operation effectively with changing water conditions
- Unload the unit and stop the unit automatically

2. Partial automation is the provision of remote or pre-programmed control over the watt and var output of the unit. Start-up and shutdown require on site operator intervention.

3. Unstaffed operation means that an operator is not required for the normal functioning of the operating equipment or the powerplant infrastructure. An operator will be required to initiate unit start-up, synchronization and shutdown. In this case provision of a secure and safe powerplant is required.

Examples of plant automation are given in the Annotated Bibliography to Volume 7.

B.7 Other Services

Opportunities to increase Other Services[1] at hydro plants are shown on Table B-6.

Table B-6
Opportunities to Increase Other Services from Hydro Plants

PRODUCT AND SERVICES	UNITS	WAYS TO ACHIEVE INCREASE	POSSIBLE BENEFITS	REFERENCE TO TECHNICAL GUIDES
Water Sales	Volume	Protection watershed		
Flood Controls		Improve river regulation		
Recreational/Environmental	Days/yr	• Install facilities • Regulate reservoir levels • Provide safe access		

Table B-6 - Notes:

1. Other services includes any external (to utility) service or intangible service provided by the plant or the impoundment for which the utility receives a financial benefit or credit.

Examples of increasing Other Services at hydro plants are contained in the Annotated Bibliography to this volume and Volume 6.

C
APPENDIX C: CASE HISTORY

C.1 Synopsis

The Case History demonstrates the Life Extension and Modernization methodology presented in these guidelines. The Case History is realistic but, in order for presentation in a clear and concise manner, certain simplifications have been made. The scenarios described would normally be far more complex than those documented herein and many more life extension and modernisation timing issues would be investigated. Also, licensing and regulatory matters would require further consideration in terms of the timing and nature of any amendments to be sought.

The level of detail presented illustrates that expected to be uncovered when the process is conducted on a 'live' plant. Financial details are based on generic North American data but, for simplicity have sometimes been modified. Each utility has its own criteria for determining a 'viable' project; this Case History does not argue the viability or otherwise of the scenario in question, but merely demonstrates a process.

In this Case History

- the results of the screening and prioritisation process show that the Francis Hydro Plant is a high ranking candidate for Life Extension and Modernization.
- The Life Extension and Modernization Plan confirms that the plant is a very attractive candidate for life extension with modernization opportunities available for increases in plant efficiency, and
- The feasibility process refines the Plan information to demonstrate the viability of the proposed modernization activities.

C.2 Background

Francis Hydro Plant is located on the shore of Coho Lake. Steelhead Lake reservoir, impounded by Big Bear Dam, provides regulated upstream storage.

Big Bear dam is a 160 ft (49 m) high, 900 ft (274 m) long earthfill/rockfill installation completed in 1948. Steelhead Lake reservoir has a capacity of 250 000 acre-feet (308.6×10^6 m^3).

A 3 mile (4.8 km) tunnel connects the intake structure on Steelhead Lake, through Pine Ridge, to the four Francis Hydro Plant penstocks which range in length between 1700 ft (518 m) and 2000 ft (609 m).

The powerhouse contains four vertical 62 MVA generators operating at 300 rpm. Each generator is coupled to a 67 000 bhp Francis reaction turbine. A governor controls the operation of the 16 wicket gates on each turbine. Maximum static head at the powerhouse is 827 ft (252 m). The units were commissioned as follows: G1 - 1948, G2 - 1949, G3 - 1950 and G4 - 1952. Each of the four units is capable of synchronous condenser operation. Average energy output for the plant is 1042 GWh.

A hydraulically (water) operated 70 inch (1.78 m) turbine inlet valve (TIV) provides hydraulic isolation of the turbine from the penstock.

Usually the plant operates for 12-16 hours of full load generation per day with the remainder involving synchronous condenser operation. Plant operating restrictions are system requirements and the downstream Coho hydro plant with a smaller hydraulic capacity.

The plant is approximately 50 years old and in that time the only major works carried out in the turbine and generator area have been the rewind of G2 and G4 generators and the automation of the plant in the early 1990s. An efficiency test of G1 was conducted in 1995 to compare actual and design performance. The results of the efficiency test indicated a peak turbine efficiency of 88%. Values of 93% peak efficiency can be expected from upgraded Francis turbine runners in this configuration. Therefore, the potential for plant improvement instigated the life extension and modernization process. Also, the wicket gates of all turbines have extensive erosion/cavitation damage and a decision on the direction of repairs to these items is necessary.

C.3 Screening and Prioritization

(Reference: Section 3 Volume 1)

The Francis hydro plant is only one of 34 plants in the utility portfolio of approximately 7000 MW owned by the utility. The screening and prioritization process detailed in Section 3 of Volume 1 was used to determine if the plant is a candidate for life extension and/or modernization. The plant:

- Is greater than 15 years old.
- Has not had a full life cycle evaluation completed within the last 5 years.
- Has no institutional and regulatory issues that render it unsuitable for life extension.
- Has suffered a gradual decline in output, reliability and availability.

(Plants ‘X’ and ‘Y’ screening results are included in the attached screening and prioritization summary sheets to illustrate the process. Details of how Plants ‘X’ and ‘Y’ results were derived will not be discussed.)

C.3.1 Life Extension Rating

All ratings are inserted on the appropriate worksheets which are found in Tables C-1 to C-4 after Section C.6.7.

Importance

The importance descriptor consists of two indicators - contribution and criticality.

Contribution

The plant has an average annual energy output of 1042 GWh out of a portfolio of 30 436 GWh, i.e. approximately 3.4%. **Rating 5**.

Criticality

Losing one unit for 6 months represents 130.25 GWh of energy @ 2¢/kWh (say) equals a loss of $2,605,000. **Rating 10**.

Dependability

The dependability descriptor consists of four indicators - condition, performance, operational risk (safety) and operating and maintenance costs.

Condition - HAVE

The plant will require some work over the next 20 years. **Rating 3 (unsatisfactory)**.

Condition - NEED

Only minor activity will be required to sustain plant output. **Rating 1**.

Performance - HAVE

The plant has more than 10 forced outages per year. **Rating 4**.

Performance - NEED

Work required will incur significant costs. **Rating 2**.

Operational Risk - HAVE

The plant has low risks and/or threats to worker safety. **Rating 1**.

Operational Risk - NEED

Work required will incur minor costs. **Rating 1**.

Operating and Maintenance Costs

Annual budget is $6,875/MW. **Rating 1**.

Sustainability

The sustainability descriptor consists of four indicators - licensing, regulatory compliance, environmental issues and catastrophic risks.

Licensing - HAVE

The plant has minor licensing issues with minimum associated process. **Rating 1**.

Licensing - NEED

Only minor activity will be required to sustain plant output. **Rating 1**.

Regulatory Compliance - HAVE

Some major issues regarding water use are arising which may present problems. **Rating 5**.

Regulatory Compliance - NEED

Significant costs may be incurred. **Rating 3**.

Environmental Issues - HAVE

Some environmental issues occur from time to time. **Rating 1**.

Environmental Issues - NEED

Only minor activity and cost to mitigate anticipated issues. **Rating 1**.

Catastrophic Risks - HAVE

Some risks to property exist due to the penstock hillside. **Rating 3**.

Catastrophic Risks - NEED

Significant activity and cost will be required to mitigate. **Rating 3**.

Calculate Overall Rating for Life Extension

The plant scores are entered into the Step 3-5 worksheet with a plant score calculated for dependability and sustainability of 44 and an importance score of 15. These are multiplied for a result of 660 which can be compared to the results from the plants shown of 330 for Plant ‘X’ and 258 for Plant ‘Y’.

C.3.2 Modernization Rating

All ratings are inserted on the appropriate worksheets which are found in Tables C-5 to C-7 after Section C.6.7.

Output

The output descriptor consists of four indicators - capacity, efficiency, staffing and equipment.

Capacity - HAVE

Water is spilled infrequently with average head ~ maximum head. **Rating 0**.

Capacity - CAN

The use of the water resource has reasonable opportunity for improvement, i.e. by modernizing turbine equipment. **Rating 2**.

Capacity - COST

Average costs would be incurred to implement opportunities. **Rating 2**.

Efficiency - HAVE

At present, there are major inefficiencies due to turbine equipment performance. **Rating 5**.

Efficiency - CAN

There are significant improvement opportunities available. **Rating 5**.

Efficiency - COST

Cost to achieve improvements is average. **Rating 2**.

Staff - HAVE

The plant is fully automated with no operating staff. **Rating 0**.

Staff - CAN

N/A.

Staff - COST

N/A.

Equipment - HAVE

The plant has some modern components and others aging. **Rating 1**.

Equipment - CAN

Significant opportunities are available to improve the use of equipment. **Rating 5**.

Equipment - COST

The relative cost for the improved equipment is average. **Rating 2**.

Flexibility

The flexibility descriptor consists of three indicators - products and ancillary services, system stability and services.

Products, Ancillary Services - HAVE

The present range and use of products is average. **Rating 3**.

Products, Ancillary Services - CAN

There are reasonable opportunities to improve the range of products. **Rating 3**.

Products, Ancillary Services - COST

The relative cost to implement improvements is significant. **Rating 2**.

System Stability - HAVE

The plant provides an average level of support. **Rating 3**.

System Stability - CAN

There are minor opportunities to improve system stability. **Rating 1**.

System Stability - COST

The relative cost to improve system stability is significant. **Rating 2**.

Services - HAVE

At present, the plant provides an average amount of services through river regulation, reservoir storage, domestic water supply and recreational benefits. **Rating 1**.

Services - CAN

There are only minor opportunities to improve services. **Rating 1**.

Services - COST

The relative cost to improve services is significant. **Rating 2**.

Calculate Overall Rating for Modernization

The plant scores are entered into the Step 3-8 worksheet with a plant score calculated for output and flexibility of 86 and an importance score of 15. These scores are multiplied for a result of 1290 which can be compared to the results from the other plants shown of 160 for Plants 'X' and 280 for 'Y'.

Prioritize Work for Life Extension or Modernization

The results for life extension and modernization ratings for the Francis Plant and Plants 'X' and 'Y' are collected in the Steps 3-5 and 3-8 worksheets respectively and compared to assess priorities amongst the plants. Francis is high in the rankings for both life extension and modernization and has a relatively high ranking across the utility's portfolio of plants. Therefore, it will be investigated to prepare a Life Extension and Modernization Plan.

C.4 Life Extension and Modernization

(References: Section 4 Volume 1, Appendix B Volume 1, Volumes 2 to 7)

C.4.1 Plant Survey

The plant survey involved:

- Planning the process.
- The formulation of an asset register.
- The collection of existing data including:
  - reports of previous assessments, studies, tests and projects
  - operational information
  - maintenance records
  - design records
- Analyzing the collected data prior to the site visit.

- Conducting a site visit using a team of 3 engineers. The visit was carried out over 2 days and involved an inspection of the plant and interviews with site staff to ascertain plant condition. No plant was taken out of service for inspection or testing during this visit.
- Collating the data into Tables 4-3 and 4-4. (Tables C-7 and C-8 after Section C.6.7.)
- Conducting a risk assessment for the plant with the assessment collated in Table 4-5. (Table C-9 after Section C.6.7). Note that several columns of Table 4-5 remain unpopulated as each utility will have its own unique ranking system to apply.
- Identifying needs for life extension and opportunities for modernization by assessing needs and opportunities from Tables 4-3, 4-4 and 4-5. A 'Needs' table is formulated (Table 4-6 Needs. [Table C-10 after Section C.6.7.]) along with an 'Opportunities' table (Table 4-6 Opportunities. [Table C-11 after Section C.6.7.]).

C.4.2 Plant Strategies

Plant strategies are formulated to assist in determining the future direction of the plant. Strategies are developed in the areas of:

- Operations
- Workforce and maintenance planning
- Risk
- Product portfolio improvements

These areas capture the important decision-making areas of hydro plant management.

Operations

The plant operation is presently at full capacity during high load hours and synchronous condensing during low load hours. This mode of operation is restricted due to a downstream plant with a smaller hydraulic capacity and the requirement (for environmental reasons) to minimize spilling water at the downstream plant. At present, there is little scope for change from this operating regime. The opportunity remains, however, to gain more energy from the water used, i.e. efficiency improvements, if possible. Projects that target efficiency improvements will be viewed favourably.

Workforce and Maintenance Planning

The plant was automated in the early 1990s and has no operational staff. Maintenance staff are presently shared with other plants in the area and further optimization is not envisaged. Contractors are also used in targeted areas.

Maintenance costs are presently split at 54% 'corrective', 30% 'preventative', 9% 'construction' and 7% 'other'. An effort is being made to bring the corrective and preventative expenditures closer together to reduce unplanned events. Condition monitoring will also be considered as part of the increase in preventative maintenance depending upon the economics of any proposal.

Risk

Risks will be addressed in the following manner:

- Life Safety - All regulatory requirements shall be met. If the regulatory requirements are not being met in any area they will be addressed immediately. Dam safety risks, which relate to life safety risk to the public, are addressed by procedures internal to the utility.
- Business Critical Risks - Generally business critical risks relate to dam safety (for this plant) and will be addressed by internal procedures.
- Financial Risks - Financial risks will be assessed for impact on the plant's operation. The risk exposure will be identified and projects which reduce the plant's risk exposure will be justified using economic/financial criteria.

Product Portfolio Improvements

The automation of the plant in the early 1990s allows the plant to be operated under automatic generation control (AGC). This ability is not required by the system at present, however. The plant already supplies synchronous condense services to the system on a daily basis. There is little scope for an improvement in the portfolio of products supplied.

C.4.3 Selected Needs and Opportunities

The results of the plant survey, in terms of needs and opportunities (life extension and modernization), are now aligned with the plant strategies developed in the previous section. A link sheet is prepared, as Table 4-7, which links the utility's strategic objectives with the individual plant strategies and the modernization projects proposed.

Following the check in Table 4-7 (Table C-12 after Section C.6.7), the Tables 4-6 'Needs' and 4-6 'Opportunities' are now revised to only include those projects which align with the strategies, i.e. those which improve plant efficiency. In this case the 'Needs' projects of Table 4-6 all align with the strategies and a revised table is not required. The revised 'Opportunities' table is Table 4-8 'Opportunities' (Table C-13 after Section C.6.7).

C.4.4 Financial Evaluation

A financial evaluation of the needs and opportunities projects summarized in Tables 4-6 'Needs' and 4-8 'Opportunities' is conducted. Costs, benefits and timing for the selected Needs and Opportunities are assigned along with the plant's income and cost forecasts (Refer to Table C-9 for required inputs).

The values assigned to the projects form the basis of the input to the example evaluation template provided with the guidelines. The outputs of the evaluation template are attached to this Case History and considered as follows:

- 20 year Financial Forecast - Life Extension provides an indication of the financial viability of the plant with no change to the products provided and maintaining the plant to provide those products for the next 20 years.
- 20 year Financial Forecast - Modernization provides an indication of the financial viability of the plant with modernization activities carried out. Various scenarios are used to compare the viability of each scenario. The scenarios investigated for Francis include:
  - Modernizing the turbine runners, stay vanes and wicket gates of all 4 units and achieving an overall efficiency improvement of 1%, 2%, 3%, 4%, 5% and 6%.

Model results from Figures C-1 and C-2 attached after Section C.6.7:

Option	Plant 20 year NPV ($M)	Plant 20 Year Benefit Cost Ratio
Life Extension	175.156	2.63
Life Extension Plus:		
Modernization - 1% Efficiency Increase	174.224	2.59
Modernization - 2% Efficiency Increase	176.699	2.61
Modernization - 3% Efficiency Increase	179.163	2.63
Modernization - 4% Efficiency Increase	181.627	2.65
Modernization - 5% Efficiency Increase	185.657	2.67
Modernization - 6% Efficiency Increase	186.548	2.70

Note that the Benefit Cost Ratio is for the whole plant, nor for the individual modernization projects. Also, the first page only of the Model results for Life Extension and 5% efficiency increase are displayed in Figures C-1 and C-2.

The financial model indicates that:

- The plant provides a reasonable level of return over the next 20 years assuming life extension activities only.
- Increasing the efficiency of the units by modernizing the turbine runners, stay vanes and wicket gates is an attractive option which warrants further investigation as long as a minimum efficiency gain of 3% (at this stage) can be realized.

C.4.5 Life Extension and Modernization Plan

A life extension and modernization plan is formulated at the completion of the financial evaluation. The financial evaluation has identified that life extension for the plant is an attractive option with a NPV of $175.156M and a Benefit Cost Ratio of 2.63. The modernization options investigated, of increasing unit efficiency by turbine runner modernization along with stay vane and wicket gate reshaping, are attractive as long as the resulting efficiency increase is at least 3%.

The life extension and modernization plan which will be taken forward to the feasibility stage will include the life extension activities listed in Table 4-6 'Needs' and the turbine runner modernization along with the modernization of the stay vanes and wicket gates. An efficiency increase of at least 3% is reasonable to expect, based on available unit efficiency data. The initial part of the feasibility study, however, will focus on determining the actual efficiency increase that can be expected from upgrading the turbine runners and reshaping the stay vanes and wicket gates. Obtaining a better estimate of the expected increase in efficiency will more accurately confirm the viability of the modernization proposal.

C.5 Feasibility

(Reference: Section 7 Volume 1)

C.5.1 Options for Feasibility

The Life Extension and Modernization Plan (the Plan) brought forward consists of two components. The Life Extension Plan (the Base Case) has been determined to be viable and will not be considered further during the feasibility process except to refine it if new information is brought to light. Usually, any new information will only further enhance the viability of the Base Case. The Modernization Plan proposes to improve plant efficiency by replacing all turbine runners with modernized equipment, and reshaping stay vanes and wicket gates. The expected increase in efficiency is approximately 4%.

The feasibility of the plant efficiency improvements will be investigated. Estimates of the costs involved and the benefits expected will be refined in consultation with manufacturers. Also the feasibility of outage timing will be considered dependent upon the feasibility of the actual plant efficiency improvements.

C.5.2 Assessment, Tests and Analysis

The modernization proposal under consideration does not require additional information to be gathered regarding the existing condition of the plant. Therefore, in this case, no additional testing of equipment is necessary.

A turbine efficiency test has previously been completed on G1 in 1995 and is considered sufficient. No further efficiency testing is required.

Further analysis of the possible efficiency gains from the Plan will be undertaken. During the formulation of the Plan it was estimated that an efficiency gain of 4% was possible for each unit. (The estimate was based on previous upgrades and preliminary discussions with manufacturers.) An engineering analysis has been conducted in association with a turbine manufacturer and the results indicated that the previous estimated efficiency gain over the existing plant can be increased from 4% to 5%.

A build ability analysis has been conducted and no problems were discovered. The powerhouse has adequate access, space and lifting capability. No other activities are planned for the plant during the planned installation periods which would interfere with the process.

Evaluate Issues

A review of the environmental and social impacts of the proposed modernization options has been undertaken. In this case there is no proposal to increase flows due to the constraint imposed by the Coho plant downstream. Also, the work proposed does not involve large changes to the powerhouse. Therefore the environmental and third party social impact of the proposal will be negligible.

The proposed modernization activities will not have any effect on the staffing of the plant. Therefore, there will be no internal social impact.

Regulatory and licensing requirements are not expected to be major impediments as plant operation and water use will not change.

A risk analysis for the modernization option under consideration provided no risks which were deemed unacceptable by the utility.

C.5.3 Evaluation of Options

The modernization option brought forward to the feasibility stage was limited to increasing the efficiency of each unit. Alternative options were not brought forward. At this stage costs of the option will be reassessed. Benefits consist of improvements in efficiency for each unit along with reductions in O&M costs.

A reassessment of the option costs reveal the following:

Option Tasks	Plan Cost ($k) per unit	Feasibility Cost ($k) per unit
Supply and Install modernized runner	$1,075	$800
Reshape stay vanes	$185	$100
Reshape wicket gates	$90	$40

A reassessment of the benefits (as discussed in Section C.5.2) has determined that total efficiency improvements of 5% are possible in lieu of the 4% previously expected.

Additional benefits, beyond increased unit efficiency and O&M cost reductions, could also be considered for the option in question. Reductions in risk costs are probable but will not be considered as they will be incremental to the efficiency increase, i.e. if the increased efficiency case is attractive then the other benefits of risk cost reduction will only further enhance the outcome of the financial model.

C.5.4 Optimization of Options

Optimization of the modernization option under consideration will consist of utilizing the example evaluation template to reassess the value of the option under consideration by entering the revised project costs and benefits are appropriate.

The outcome of the template calculations (refer to Figure C-3 after Section C.6.7) reveals that the efficiency improvement forecast will have the following benefits:

Option	Original Plan		Feasibility	
	Plant 20 Year NPV ($M)	Plant 20 Year Benefit Cost Ratio	Plant 20 Year NPV ($M)	Plant 20 Year Benefit Cost Ratio
Life Extension	175.156	2.63	175.156	2.63
Life Extension plus:				
2% Efficiency Increase	176.699	2.61	179.628	2.62
3% Efficiency Increase	179.163	2.63	182.093	2.64
4% Efficiency Increase	181.627	2.65	184.556	2.67
5% Efficiency Increase	185.657	2.67	187.355	2.71

Note that the Benefit Cost Ratio is for the whole plant, not for the individual modernization projects. Also, the first page only of the Model results for feasibility level 5% efficiency increase is displayed in Figure C-3.

C.5.5 Selection of Feasible Project

The evaluation template has confirmed that the replacement of the existing turbine runners with modernized versions, along with the reshaping of stay vanes and wicket gates, is attractive if an efficiency increase of 5% (as forecast) is achieved. It has also confirmed that plant efficiency increases of 3% and 4% are also attractive on a Plant 20 Year NPV basis.

As the modernization activities have been confirmed as feasible, the modernization project is now documented including:

- A description of the work proposed
- An estimate of project costs, benefits and schedule
- A summary of licensing and other issues
- A finance, risk and insurance plan
- An implementation plan

C.6 Project Definition and Implementation

(References: Section 8 Volume 1, Volumes 2 to 7)

C.6.1 Project Plan

The feasibility process provided a modernization approach with proven technical and financial viability. A Project Plan was developed to ensure that an outline exists of how the project would be undertaken including a summary of responsibilities, authorities, costs, schedules and deliverables. Confirmation of the plant owner's requirements concerning the modernization of the plant and a Quality Plan also formed part of the Project Plan.

C.6.2 Licensing and Financing

Licensing

The modernization activities proposed will have no effect on the mode of operation of the Francis Hydro Plant and there will be no effect on the rated generator capacity of the plant. Therefore, a non-capacity related amendment to the Francis license will be required.

The non-capacity related amendment process involves a letter to FERC describing the purpose and scope of the amendment requested and includes any relevant correspondence from resource agencies. Amended license exhibits are also submitted.

The license amendment is received from FERC allowing the project to proceed. No other regulatory approvals are required.

Note: It is recognized that the licensing portion of the process will generally be far more involved that the scenario presented here. The purpose of the Case History is to demonstrate the process involved with using the Guidelines. Recognizing that licensing issues associated with any one plant are unique, it is considered that a detailed licensing scenario would not serve to demonstrate the process any better than a high level scenario.

Financing

The modernization project will be financed internally by the utility. The utility's policy has been to utilize this process across its portfolio of plants and this allows all similar projects to be ranked internally and capital finds to be allotted to the most favourable projects across the utility. The Francis project is ranked highly and the necessary capital funds are allocated but will not be finally approved for expenditure until later in the implementation process.

C.6.3 Project Approval

Project approval is sought with a detailed submission to the appropriate level of management within the utility. An initial level of approval was gained with the allotting of capital funds towards the project. A detailed submission for the commitment of funds for engineering and detailed design is sought at this time. A further submission will be required for the commitment to contracts for the supply and installation of equipment at a later date.

The utility approves the funding for engineering studies and detailed design.

C.6.4 Engineering

For this project it has been decided to conduct a CFD analysis of the revised turbine runner design along with the reshaping of the associated stay vanes and wicket gates. Physical modelling will not be carried out for this project. The size of the project does not justify the use of physical modelling.

A manufacturer has been selected in a bidding process to conduct the CFD analysis. The contract has been split into two components. The first is the CFD analysis stage and the second, the supply and installation of the runners along with the stay vane and wicket gate reshaping, will be an option until the successful conclusion of the CFD analysis.

The results of the CFD analysis indicate that the 5% efficiency gain forecast is accurate and a commitment will be made to the second component of the contract.

C.6.5 Procurement

The procurement process for undertaking the modernization project involves the following:

- Preparation of tender documents for:
  - CFD analysis of the proposed works.
  - Supply and installation of modernized turbine runners and reshaping of stay vanes and wicket gates.
- Issue of tender documents on an open tender basis.
- Receive tenders and select preferred bidder.
- Award contract.

As outlined in Section C.6.4, the specification is separated into two components - the CFD analysis and the actual upgrade works. Prices will be locked in for both specification components at the award of the contract. The upgrading works, however, have been included in the specification as an option, only to be exercised by the utility upon a successful outcome for the CFD analysis.

Four tenders were received and the successful bidder selected with a tender price of $3,250 k for the CFD analysis and all other works associated with the modernization project. When the utility's costs are added the total project cost is forecast to be $3,750 k which is approximately $10 k under budget.

C.6.6 Construction

Following the successful CFD analysis, the utility exercised the option for the supply and installation of the four new turbine runners and the reshaping of the stay vanes and wicket gates. The work has been split over 2 years with two units being completed per year.

The manufacture and site works were completed without incident to program and within budget. Commissioning tests revealed a 4.8% increase in efficiency - within acceptable limits.

C.6.7 Documentation

The entire project definition and implementation process was documented in the form of a design/construction report. The purpose of the report is to provide a record of the modernization process which, due to the longevity of hydro plants, will be a useful record when the life extension and modernization process is revisited in the future. The report includes:

- Design criteria
- As-built drawings
- Changes
- Test results
- Deficiencies
- Photographs

Revised operating and maintenance manuals were also provided to update the existing manuals to include information regarding the modernized plant's performance data, troubleshooting information and maintenance requirements.

Table C-1
Step 3-2 Worksheet: Plant Importance

COMPONENT	CONTRIBUTION (HAVE)		CRITICALITY (HAVE)		TOTAL
Francis	5	+	10	=	15
Plant X	10	+	10	=	20
Plant Y	5	+	1	=	6

Table C-2
Step 3-3 Worksheet: Dependability

	CONDITION					PERFORMANCE					OPERATION RISK (SAFETY)					O&M COST
COMPONENT	**HAVE**		**NEED**		**LIFE EXT**	**HAVE**		**NEED**		**LIFE EXT**	**HAVE**		**NEED**		**LIFE EXT**	**HAVE**
Francis	3	x	2	=	6	4	x	2	=	8	1	x	1	=	1	1
Plant X	0	x	-	=	0	1	x	1	=	1	0	x	-	=	0	2.5
Plant Y	2	x	2	=	4	2	x	2	=	4	1	x	1	=	1	2

Notes: HAVE: Present situation (What we "have" at present.)
NEED: Requirement for life extension (What "needs" to be done.)
LIFE EXT: Life extension rating for specific indicator, calculated as the product of "HAVE" and "NEED".

Ratings for each plant are entered into the Overall Ratings for Life Extension (Step 3-5 Worksheet).

Table C-3
Step 3-4 Worksheet: Sustainability

	LICENSING					REGULATORY COMPLIANCE					ENVIRONMENT					CATASTROPHIC RISK				
COMPONENT	**HAVE**		**NEED**		**LIFE EXT**	**HAVE**		**NEED**		**LIFE EXT**	**HAVE**		**NEED**		**LIFE EXT**	**HAVE**		**NEED**		**LIFE EXT**
Francis	1	x	1	=	1	5	x	3	=	15	3	x	1	=	3	3	x	3	=	9
Plant X	3	x	2	=	6	3	x	1	=	3	3	x	1	=	3	1	x	1	=	1
Plant Y	5	x	2	=	10	5	x	3	=	15	3	x	2	=	6	1	x	1	=	1

Notes: HAVE: Present situation (What we "have" at present.)

NEED: Requirement for life extension (What "needs" to be done.)
LIFE EXT: Life extension rating for specific indicator, calculated as the product of "HAVE" and "NEED".

Ratings for each plant are entered into the Overall Ratings for Life Extension (Step 3-5 Worksheet).

Table C-4
Step 3-5 Worksheet: Overall Ratings for Life Extension (For Each Plant)

INDICATOR	PLANT SCORE*			COMMENTS
DEPENDABILITY	Francis	Plant X	Plant Y	
Condition	6	0	4	
Performance	8	1	4	
Safety	1	0	1	
Cost	1	2.5	2	
SUSTAINABILITY				
Licensing	1	6	10	
Compliance	15	3	15	
Environmental	3	3	6	
Catastrophic Risk	9	1	1	
TOTAL	44	16.5	43	
IMPORTANCE				
Contribution Criticality	15	20	6	
OVERALL				
Total * Importance	660	330	258	

* For each indicator, this is the sum of the “LIFE EXT” column on the screening worksheets for dependability and sustainability.

Table C-5
Step 3-6 Worksheet: Output

	CAPACITY (WATER RESOURCE)							EFFICIENCY (WATER USE)							STAFF							EQUIPMENT						
COMPONENT	**HAVE**		**CAN**		**COST**		**MODERN**	**HAVE**		**CAN**		**COST**		**MODERN**	**HAVE**		**CAN**		**COST**		**MODERN**	**HAVE**		**CAN**		**COST**		**MODERN**
Francis	0	x	2	x	2	=	0	5	x	5	x	2	=	50	0	x	1	x		=	0	1	x	5	x	2	=	10
Plant X	0	x		x		=	0	1	x	1	x	2	=	2	0	x		x		=	-	0	x		x		=	-
Plant Y	3	x	1	x	1	=	3	1	x	3	x	1	=	3	3	x	3	x	1	=	9	1	x	3	x	2	=	6

Notes: HAVE: Present situation (What we "have" at present.)
CAN: Opportunities for modernization (What "can" be done to improve the output.)
COST: Relative cost to increase output.
MODERN: Modernization rating for the component, calculated as the product of "HAVE", "CAN", and "COST".

Ratings for each plant are entered into the Overall Ratings for Modernization (Step 3-8 Worksheet).

Table C-6
Step 3-7 Worksheet: Flexibility

	PRODUCTS							SYSTEM SUPPORT							SERVICES						
COMPONENT	**HAVE**		**CAN**		**COST**		**MODERN**	**HAVE**		**CAN**		**COST**		**MODERN**	**HAVE**		**CAN**		**COST**		**MODERN**
Francis	3	x	3	x	2	=	18	3	x	1	x	2	=	6	1	x	1	x	2	=	2
Plant X	3	x	1	x	2	=	6	0	x	-	x	-	=	0	0	x	-	x	-	=	0
Plant Y	5	x	1	x	1	=	5	3	x	1	x	1	=	3	1	x	1	x	1	=	1

Notes: HAVE: Present situation at plant (What we "have" at present.)
CAN: Opportunities for modernization (What "can" be done to improve the flexibility.)
COST: Relative cost to increase flexibility.

MODERN: Modernization rating for the component, calculated as the product of "HAVE", "CAN" and "COST".

Ratings for each plant are entered into the Overall Ratings for Modernization (Step 3-8 Worksheet).

Table C-7
Step 3-8 Worksheet: Overall Ratings for Modernization (For Each Plant)

INDICATOR	PLANT SCORE*			COMMENTS
OUTPUT	Francis	Plant X	Plant Y	
Capacity	0	0	3	
Efficiency	50	2	3	
Staff	0	0	9	
Equipment	10	0	6	
FLEXIBILITY				
Products	18	6	5	
System Support	6	0	3	
Services	2	0	1	
TOTAL	86	8	30	
IMPORTANCE				
Contribution and Criticality	15	20	6	
OVERALL				
Total * Importance	1290	160	180	

* For each indicator, this is the sum of the Modernization columns on the screening worksheets for output and flexibility.

Table C-8
Table 4-3 - Step 4-2: Data Analysis Table for Francis Hydro Plant

Performance Indicator	Descriptor or Issue	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet needs (including timing and cost)	Possible Modernization Opportunities	Activities to Achieve Opportunities (including timing and cost)
Dependability	• Reliability • Availability • Maintainability • Safety and Operational Risks	• ~12 forced outages/yr • % time in planned, maintenance and forced outages/yr - 4.1%. • Annual maintenance budget: $6,875/MW. $39/hr operation/unit. • Safety risks low. • Operational risks low.	• Maintenance costs split at 54% corrective, 30% preventative, 9% construction and 7% other.	• Reduce corrective maintenance costs closer to preventative maintenance.		• Investigate possibilities for condition based maintenance in lieu of time based maintenance to attempt to reduce maintenance costs.	
Sustainability	• Licensing • Regulatory Compliance • Environmental Compliance • Catastrophic Risk	• Water licensing issues minimal at present.	• Seismic investigations are not yet complete to organizational standards. Items identified from Phase I study are yet to be completed. • Oil spill containment not up to corporate standard. • Governor/bearing oil systems do not have fire protection.	• Continue seismic investigations. • Upgrade oil spill containment. • Upgrade fire protection systems.	• Complete Phase I items and conduct Phase II seismic investigation in 1999 - $200k. • Upgrade oil spill containment in 2003 - $700k. • Revise fire system to current standards in 1998 - $475k.		

Table C-8
Table 4-3 - Step 4-2: Data Analysis Table for Francis Hydro Plant (continued)

Performance Indicator	Descriptor or Issue	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet needs (including timing and cost)	Possible Modernization Opportunities	Activities to Achieve Opportunities (including timing and cost)
Output	• Water Utilization • Generation • Reservoir Operation • Workforce Costs	• Spill has occurred only 9 years in last 40 years. • High load operation is high at present with generation in peak times 12-16 hours per day and synch. cond. at other times. • Authorized storage of 250 000 acre-feet (308.6×10^6 m^3) in Steelhead Reservoir. • Water licenses provide a total diversion rate for water power of 3624 cfs (106.2 m^3/s). • Max. spill design capacity is 13 125 cfs (372 m^3/s). • Turbine release at max. output is 905.7 cfs (26.53 m^3/s)/unit = 3624 cfs (106.12 m^3/s) for plant.	• Given the small scope for increase in water use with present situation, improving the efficiencies of existing plant appears desirable. Existing efficiencies are lower than possible due to unit wear and tear and the age of the existing design.	• Nil	• Nil	• Upgrade turbine, stay vanes and wicket gate arrangement to increase efficiency. • Upgrade turbine runner design to improve efficiency. • Uprate generators to match turbine output.	• Upgrade stay vanes, wicket gates and runners at ~$1,500k/ unit. (Assume timing 1999 and 2000 - 2 units per year). • Rewind G1 and G3 generators ~$850k/unit . (Assume timing G1 - 2001 and G3 - 2002).

Table C-8
Table 4-3 - Step 4-2: Data Analysis Table for Francis Hydro Plant (continued)

Performance Indicator	Descriptor or Issue	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet needs (including timing and cost)	Possible Modernization Opportunities	Activities to Achieve Opportunities (including timing and cost)
		• Spill is to be avoided if at all possible due to downstream environmental effects. • Bottleneck exists at Coho downstream due to capacity limit. With no increase in capacity at Coho improvements in water usage at Francis are not likely. • Plant has been automated so staff numbers have been reduced to optimum already. • Contractors are used for specialty works					
Flexibility	• Product Mix	• Av. Energy Output: 1042 GWh/yr. • Generator Nameplate Capacity: 204 MW. • Normal MCR: 200 MW. • Operated to attempt to keep hydraulic balance with downstream plant (which has lower capacity).	• Existing strategy aims for capacity at the expense of efficiency. Little scope for change in amount of water available for use except if capacity of downstream plant is increased.				

Table C-8
Table 4-3 - Step 4-2: Data Analysis Table for Francis Hydro Plant (continued)

Performance Indicator	Descriptor or Issue	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet needs (including timing and cost)	Possible Modernization Opportunities	Activities to Achieve Opportunities (including timing and cost)
		• Provides transmission support for local load and voltage support for export purposes. • Synchronous condense operation overnight. • Contributes to spinning reserve of system. • Generate heavy load during day. • Normally operated on AGC but this service not normally required for system needs.					
Profitability	• Return on Assets • NPV	• Return on Assets is <> • NPV - $98.8 M.	• Value of plant may be able to be increased via turbine upgrades. Need to investigate viability. • PV of revenue forecast for next 20 years - $205.8 M • Average yearly net energy forecast for next 20 years - 1045 GWh. • Average yearly ancillary services forecast for next 20 years - 387.7 GVARh.				

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.0	**Generating Units**						
1.1 1.2 1.3 1.4	**Generating Unit 1** **Generating Unit 2** **Generating Unit 3** **Generating Unit 4**						
1.1.1 1.2.1 1.3.1 1.4.1	**Turbines - G1 to G4**						
1.1.1.1 1.2.1.1 1.3.1.1 1.4.1.1	**General** • G1 commissioned 1948 • G2 commissioned 1949 • G3 commissioned 1950 • G4 commissioned 1952 All Francis reaction type. <u>Ratings</u> Head - 710 ft (216.21 m) net Output - 67 000 hp (49.98 MW) Efficiency (1995 test) Full Gate - 84% Best - 88% Speed - 300 rpm Wheel Capacity 937 cfs (26.53 m^3/s)/unit	• Up to 52 MW available depending on lake level.				• Improve efficiency by reshaping stay vanes.	• Reshape stay vanes $185k per unit. • G1, G2 - 1999 • G3, G4 - 2000
1.1.1.2 1.2.1.2 1.3.1.2 1.4.1.2	**Runners - G1 to G4**	• Cavitation inspections and repair by grinding bi-annually.	• Indefinite life expectancy.	• Nil	• Nil	• Potential for upgrading by runner replacement with a newer design to improve efficiency.	• Supply and install redesigned runners $1,075k per unit. G1, G2 - 1999 G3, G4 - 2000.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.1.3 1.2.1.3 1.3.1.3 1.4.1.3	**Wicket Gates, Servomotors – G1 to G4**	• Wicket gates have extensive cavitation /erosion damage which is affecting unit efficiencies. • Needle servomotor piston rings have never been replaced. • Wicket gate bushings have never been replaced.	• Damage not fully repairable without complete refurbishing or replacement.	• Refurbish or repair all wicket gates. • Replace servomotor piston rings.	• G1 • Refurbish servomotors in 2001 - $120K. • Refurbish wicket gates in 2001 - $100k. • G2 • Refurbish servomotors in 1998 - $120K. • Refurbish wicket gates in 1998 - $100k. • G3 • Refurbish servomotors in 2002 - $120K. • Refurbish wicket gates in 2002 - $100k. • G4 • Refurbish servomotors in 2000 - $120K. • Refurbish wicket gates in 2000 - $100k.	• Reshape wicket gates to improve efficiency.	• Reshape wicket gates $90k per unit. G1, G2 – 1999 G3, G4 – 2000.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.1.4 1.2.1.4 1.3.1.4 1.4.1.4	**Turbine Bearings and Lube System - G1 to G4**	• Bearings still original and in good condition. • G2 was wiped and repaired - date unknown.	• Indefinite life expectancy. • Oil reservoir has temperature alarm only - no level sensing provided. • Some problems with oil coolers and pumps.	• Add level sensing equipment. • Refurbish oil coolers and pumps	• G1 • Refurbish oil cooling system/pumps and add level sensing equipment in 2001 - $132k. • Permanent lift pump units in 2001 - $110k • G2 • Refurbish oil cooling system/pumps and add level sensing equipment in 1998 - $132k. • Permanent lift pump units in 1998 - $110k • G3 • Refurbish oil cooling system/pumps and add level sensing equipment in 2002 - $132k. • Permanent lift pump units in 2002 - $110k • G4 • Refurbish oil cooling system/pumps and add level sensing equipment in 2000 - $132k. • Permanent lift pump units in 2000 - $110k		

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.2 1.2.2 1.3.2 1.4.2	**Governors - G1 to G4**						
1.1.2.1 1.2.2.1 1.3.2.1 1.4.2.1	**Hydraulic Systems - G1 to G4** G1 to G4		• G1 to G3 generally good condition. • G4 - high maintenance, sloppy control, high internal oil leakage - pump runs a lot. • Life expectancy • G1 to G3 - 20 years. • G4 - 5 years.	• Replace oil every 7 years. • Rebuild oil pumps in 3 years.	• G1 • Rebuild hydraulic pump system in 2014 - $240k. • G2 • Rebuild hydraulic pump system in 2013 - $240k. • G3 • Rebuild hydraulic pump system in 2015 - $240k. • G4 • Rebuild hydraulic pump system in 2000 - $240k.	• Replace pumps with modernized versions.	• G1 • Replace hydraulic pump with modernized version in 2014 - $300k. • G2 • Replace hydraulic pump with modernized version in 2013 - $300k. • G3 • Replace hydraulic pump with modernized version in 2015 - $300k. • G4 • Replace hydraulic pump with modernized version in 2000 - $300k.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.2.2 1.2.2.2 1.3.2.2 1.4.2.2	**Governor Controls - G1 to G4**		• G1 to G3 good condition. • G4 fair condition. • Life expectancy • G1 to G3 - 20 years. • G4 - 10 to 15 years.	• Inspect and repair bearings and seals in governor components and restoring mechanisms.	• G1 • Replace governor, valves, aux. Items in 2014 - $1,700k. • G2 • Replace governor, valves, aux. Items in 2013 - $1,700k. • G3 • Replace governor, valves, aux. Items in 2015 -$1,700k. • G4 • Replace governor, valves, aux. Items in 2006 -$1,700k.	• Upgrade to digital control.	• G1 • Upgrade governor to digital control in 2014 - $185k. • G2 • Upgrade governor to digital control in 2013 - $185k. • G3 • Upgrade governor to digital control in 2015 - $185k. • G4 • Upgrade governor to digital control in 2006 - $185k.
1.1.3 1.2.3 1.3.3 1.4.3	**Turbine Inlet Valves - G1 to G4** Type - spherical valve Operating System -hydraulic		• Generally good condition. • Some control valve problems. • Indefinite life expectancy.	• Modify control valving to eliminate problems.		• Nil	
1.1.3.1 1.2.3.1 1.3.3.1 1.4.3.1	**Valve**						
1.1.3.2 1.2.3.2 1.3.3.2 1.4.3.2	**Actuator**				• G1 - Modify control valving in 2001 - $190k. • G2 - Modify control valving in 1998 - $190k. • G3 - Modify control valving in 2002 - $190k. • G4 - Modify control valving in 2000 - $190k.		

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.4 1.2.4 1.3.4 1.4.4	**Generators - G1 to G4** 62 MVA, 13.8 kV, 300 rpm, 3 phase						
1.1.4.1 1.2.4.1 1.3.4.1 1.4.4.1	**Stators - G1 to G4**	• G1 rewedged 1979 • G2 rewound 1987 • G3 rewedged 1981 • G4 rewound 1973	• G1 and G3 - May require rewinds shortly after testing due next 2 years. • Life expectancy • G1 and G3 - 5 years • G2 and G4 - 35 years	• Rewind G1 and G3.	• G1 - Rewind stator winding in 2001 - $850k. • G2 - Clean and rewedge in 2008 - $150k. • G3 - Rewind stator winding in 2002 - $850k. • G4 - Clean and rewedge in 2000 - $150k.	• Rewind G1 and G3 for uprate. Note that this will occur under life extension and an uprate will automatically be expected due to the use of modern materials. • G2 and G4 already rewound with increased rating of 52 MW. • Pre-purchase generator re-build parts to reduce the cost of an extended outage due to a major generator failure.	• Refer to life extension column for uprate details. • Pre-purchase of generator winding in 1998 - $400k.
1.1.4.2 1.2.4.2 1.3.4.2 1.4.4.2	**Rotors - G1 to G4**	• G1 poles rebuilt 1990 • G4 blocking added between poles 1991.		• G1 - requires blocking between poles. • G2 - requires blocking between poles. • G3 - requires blocking between poles and new rotor bus cables.	• G1 - Rebuild rotor in 2001 - $800k. • G3 - Rebuild rotor in 2002 - $800k.		

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.4.3 1.2.4.3 1.3.4.3 1.4.4.3	**Generator Bearings and Lubrication - G1 to G4.**						
1.1.4.4 1.2.4.4 1.3.4.4 1.4.4.4	**Braking System - G1 to G4**						
1.1.4.5 1.2.4.5 1.3.4.5 1.4.4.5	**Stator Coolers - G1 to G4**		• All coolers rapidly approaching end of service life.	• Replace all coolers G1 to G4.	• G1 • Replace cooler in 1999 - $100k. • G2 • Replace cooler in 1999 - $100k. • G3 • Replace cooler in 1999 - $100k. • G4 • Replace cooler in 1999 - $100k.	• Nil.	• Nil.
1.1.4.6 1.2.4.6 1.3.4.6 1.4.4.6	**Generator Fire Protection - G1 to G4**						
1.1.5 1.2.5 1.3.5 1.4.5	**Excitation System - G1 to G4** Digital Static Exciter Input: 209 VAC, 655 Aac, 3 phase Output: 186 VDC, 800 Adc cont., 1280 Adc for 30 sec. Note: Slip rings of old direct coupled exciter are still being used.	• G1 to G4 exciters have been previously upgraded to digital static excitation (date unknown).	• Life expectancy for all 4 exciters of 40 years.	• Nil	• Nil	• Nil	• Nil

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.6 1.2.6 1.3.6 1.4.6	**Unit Protection and Control - G1 to G4**						
1.1.6.1 1.2.6.1 1.3.6.1 1.4.6.1	**Unit Protection Panels P1 and P2 - G1 to G4** All panels (2 per unit) are located in the powerhouse relay rooms and provide for each unit: P1 - protection for primary (86G), standby (86GS) and normal lockout shutdown (86N) for both generator, turbine and excitation trips. P2 - protection for generator out of step, stator overvoltage, negative sequence, backup impedance, stator overtemperature, incomplete start sequence and exciter crowbar overcurrent protection.	• Relays in all panels were substituted in 1990. • Power supply cards type ìTTî are now obsolete. Replacement ìMEî card is available.	• Minimum life expectancy: • Protection relays - 30-35 years. • Indicators, circuit boards and auxiliary relays - 20-25 years.	• Scheduled testing only.	• Nil	• Replace individual relays with microprocessor controlled relay package.	• Replace G1 to G4 relays in 2005 @ $60k. Total = $240k.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.6.2 1.2.6.2 1.3.6.2 1.4.6.2	**Unit Control Panels** **G1 - Panel F3, R3** **G2 - Panel F4, R4** **G3 - Panel F5, R5** **G4 - Panel F2, R2** All panels are located in the powerhouse control room and provide turbine/generator unit controls, metering, unit alarm displays and stator temperature monitoring (bearing monitoring panels are located near the units on the generator floor.	• All panels built as part of the Remote upgrade project in 1990.	• G1 to G4: • 65LXSP which lowers the power setting during transition from gen to synch cond operation prematurely drops out due to the drifting of the limit switch 65SPL. • The power supply 3TS is now obsolete and has experienced failure. New replacements (MTS Card) are available. • G3: Temp monitoring op amp (WD card) is causing a false alarm on one of the RTD readouts. • Minimum life expectancy for all units - 20-25 years.	• Short term repairs from previous column. • Scheduled testing only.	• Nil	• Replace with HMI system and new metering system.	• Install HMI system and new metering system for G1 to G4 in 2005 @ $300k. Total = $1,200k.
1.1.6.3 1.2.6.3 1.3.6.3 1.4.6.3	**Alarm Indication and Monitoring - G1 to G4**						
1.1.6.4 1.2.6.4 1.3.6.4 1.4.6.4	**Synchronizing System - G1 to G4**						

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.7 1.2.7 1.3.7 1.4.7	**Unit Circuit Breakers - 13CB1, 13CB2, 13CB3, 13CB4** Circuit breaker type C532X, bulk oil circuit breaker, 15 kV, 3,000 A continuous, disconnects combined into these units	• Installed in 1946.	• Circuit breakers are in fair condition. • Oil was black when changed, otherwise good. • Mechanical wear is reasonable. • Contacts in reasonable condition. • Bushings starting to show their age.	• Major overhaul in 5 years for all breakers.	• G1 - Major overhaul in 2002 - $70k. • G2 - Major overhaul in 2003 - $70k. • G3 - Major overhaul in 2003 - $70k. • G4 - Major overhaul in 2002 - $70k.	• Nil	• Nil
1.1.8 1.2.8 1.3.8 1.4.8	**Generator LV Leads and Terminal Equipment - G1 to G4**						
1.1.8.1 1.2.8.1. 1.3.8.1 1.4.8.1	**Generator Neutrals - G1 to G4** Distribution grounding transformers, disconnect switches (13D1-4), ground resistors.	• All equipment for grounding was built in the last 4 - 5 years.	• Minimum life expectancy - 20-25 years (equipment seldom in service - short time during a fault)	• Nil	• Nil	• Nil	• Nil
1.1.8.2 1.2.8.2 1.3.8.2 1.4.8.2	**Generator Bus - G1 to G4** Generator Bus connects generator terminals with LV side of the power transformers, PVC XLPE cable - 2 x 2000 KCMIL, 15 kV, Strain bus - twin 1272 KCMIL, ASC NARCISSUS, PVC XLPE cable, 2000 KCMIL	• Strain bus was recently installed.	• Minimum life expectancy – 20-25 years.	• Nil	• Nil	• Nil	• Nil

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.8.3 1.2.8.3 1.3.8.3 1.4.8.3	**Generator Switchgear - CTs and PTs.** **CTs1-8, G1 to G4.** **13VT1-3, G1 to G4** **13VTB1-B4** **13VT1T1and2, 13VT2T2** Current transformers: 3000:5 A, built into the generator CB bushings, generator neutral current transformer housing. Potential transformers: moulded type with fuses for 13 800 - 115 - 115 V, 60 Hz	• All CTs and PTs are original.	• Minimum life expectancy - 10-15 years	• Replace CTs and PTs.	• G1 - replace CTs and PTs in 2010 - $38k. • G2 - replace CTs and PTs in 2010 - $38k. • G3 - replace CTs and PTs in 2010 - $38k. • G4 - replace CTs and PTs in 2010 - $38k.	• Nil	• Nil
1.1.8.4 1.2.8.4 1.3.8.4 1.4.8.4	**Generator Switchgear - Arresters and Capacitors - G1 to G4.** Arresters: Valve type surge arresters, single pole.	• All arresters are original. • All capacitors replaced within the last 10 years.	• Minimum life expectancy: • Arresters - 8-10 years • Capacitors - 20-25 years.	• On a long term basis replace arresters with ZnO type which have better voltage distribution characteristics under normal and abnormal service conditions.	• G1 - replace arresters in 2006 - $32k. • G2 - replace arresters in 2007 - $32k. • G3 - replace arresters in 2007 - $32k. • G4 - replace arresters in 2006 - $32k.	• Nil	• Nil
1.1.8.5 1.2.8.5 1.3.8.5 1.4.8.5	**Generator Switchgear - Disconnect Switches 13D11, 13D12, 13D13.**	• All disconnecting switches are original.	• Minimum life expectancy - 10-15 years.	• Major overhaul	• G1 - major overhaul in 2011 - $36k. • G3 - major overhaul in 2012 - $18k.	• Nil	• Nil

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.1.9	**Generator Transformers T1A, T1B, T1C (collectively T1)** Oil type, 18 MVA, single phase, 13.8 kV - 230 kV.	• Installed in 1959. • Heat exchangers replaced in all transformers in 1990.	• Fair condition based on latest test results and increasing levels of items extracted from oil, dissolved gases and Furan analyses. • Minimum life expectancy - 10-15 years.	• Continued oil sampling, dissolved gas testing and Furan analysis is recommended to establish trends and confirm advanced aging of the insulation system. • Replace longer term.	• T1A - replace in 2005 - $350k. • T1B - replace in 2008 - $350k. • T1C - replace in 2007 - $350k. • T1 protection and alarms - replace pilot wire relay in 2009 - $17k.	• Install on-line gas in oil monitoring system.	• Install system in 2002 - $200k.
1.2.9	**Generator Transformers T2A, T2B, T2C (collectively T2)** Oil type, 18 MVA, single phase, 13.8 kV - 230 kV.	• Installed in 1960 • T2A rebuilt in 1989 (HV winding, heat exchanger replacement and bushing repair). • T2B heat exchanger replaced in 1989. • T2C rebuilt 1989 (HV winding, tap changer and heat exchanger replacement).	• T2A - good condition. • T2B - poor condition. • T2C - excellent condition. • Latest oil quality results for T2B indicate increasing levels of H2 (low energy discharge). • Minimum life expectancy - 10-15 years.	• Continued oil sampling, dissolved gas testing and Furan analysis is recommended to establish trends and confirm advanced aging of the insulation system. • Replace longer term.	• T2A - replace in 2009 - $350k. • T2B - replace in 2010 - $350k. • T2C - replace in 2012 - $350k. • T2 protection and alarms - replace pilot wire relay in 2009 - $17k.	• Install on-line gas in oil monitoring system.	• Install system in 2004 - $200k.
1.3.9	**Generator Transformers T3A, T3B, T3C (collectively T3)** Oil type, 18 MVA, single phase, 13.8 kV - 230 kV.	• Installed in 1959. • Heat exchangers replaced in all transformers in 1990.	• Minimum life expectancy - 10-15 years.	• Continued oil sampling, dissolved gas testing and Furan analysis is recommended to establish trends and confirm advanced aging of the insulation system. • Replace longer term.	• T3A - replace in 2011 - $350k. • T3B - replace in 2013 - $350k. • T3C - replace in 2014 - $350k. • T3 protection and alarms - replace pilot wire relay in 2009 - $17k.	• Install on-line gas in oil monitoring system.	• Install system in 2002 - $200k.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
1.4.9	**Generator Transformers T4A, T4B, T4C (collectively T4)** Oil type, 18 MVA, single phase, 13.8 kV - 230 kV.	• Heat exchangers replaced in all transformers in 1990.	• T4A - good condition. • T4B - poor condition. • T4C - excellent condition. • Minimum life expectancy - 10-15 years	• Continued oil sampling, dissolved gas testing and Furan analysis is recommended to establish trends and confirm advanced aging of the insulation system. • Replace longer term.	• T4A - replace in 2015 - $350k. • T4B - replace in 2014 - $350k. • T4C - replace in 2016 - $350k. • T4 protection and alarms - replace pilot wire relay in 2009 - $17k.	• Install on-line gas in oil monitoring system.	• Install system in 2004 - $200k.
2.0	**Powerhouse**						
2.1	**Powerhouse Auxiliary Equipment and Systems**						
2.1.1	**Station Service AC** AC distribution for the powerhouse is fed from the new 480 V switchgear and consists of a combination of 480 V panels, MCC and 240/120 V panels of different manufacturers and ages. The 480 V systems are ungrounded	• Distribution panels for the unit auxiliaries are original equipment.	• Very good condition. • Replacement of parts will become more difficult in the future.	• Relocate and replace 120/240/480 V lighting distribution gallery panel. • Replace distribution panels for units.	• Relocate and replace 120/240/480 V lighting distribution gallery panel in 1998 - $60k. • Replace distribution panels for units in 2006 - $68k.	• Add emergency station services panel.	• Add emergency station services panel in 2002 - $80k.
2.1.1.1	**Circuit Breakers and Disconnects - 480 V Switchgear** 480 V switchgear consisting of 3 sections of 1600 A buses, 3 600 A incomers and 2 tie breakers, 4 600 A feeder breakers for unit switchboards and 1 400 A feeder breaker for auxiliary station service.	• Installed in 1992	• Minimum life expectancy - 20-25 years.	• Nil	• Nil	• Nil	• Nil

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
2.1.1.2	**Transformers and Reactors - Transformers T11, T12 and T13.** Station Service Transformers Oil type, 300 kVA, 3 phase, 13.8 kV - 460 V, with LTC	• In service about 1965.	• All transformers in poor condition based on previous oil quality analyses. • Minimum life expectancy - 5-10 years.	• Replace transformers	• T11, T12 and T13 - replace all in 2004 - $597k.	• Nil	• Nil
2.1.1.3	**Standby Power Supply**						
2.1.1.4	**Protection and Control** Transformer P and C panels T11/12, T13 R6 Protection for station service transformers comprises overcurrent relays for the HV winding and ground fault zero sequence voltage detectors for the LV winding. A Man/Auto transfer scheme is provided at Panel R6. Transformers are equipped with OLTC and a remote TC control panel.		• Excellent condition. • Minimum life expectancy - 25-30 years.	• Scheduled testing only.	• Nil	• Nil	• Nil
2.1.2	**Station Service DC** • 125 VDC distribution systems consist of one main distribution board and unitized dc sub-panels for units and sub-panels for the control room. The main distribution panel is equipped with Westinghouse breakers. The sub-panels are equipped with Stotz type breakers. • 24 VDC panels are equipped with Stotz type breakers.	• Main distribution panel is original equipment.	• Main distribution panel is in fair condition. • Sub-panels are in very good condition. • Minimum life expectancy - Main distribution panel - 10-15 years. Sub-panels - 20-25 years.	• Scheduled testing only. • Replace main distribution panels in longer term.	• Replace main distribution panels in 2009 - $31k.	• Nil	• Nil

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
2.1.2.1	**Battery and Charger Systems** 125 and 24 VDC battery chargers provide power supply for P&C functions and communications respectively.	• 125 V lead acid batteries were replaced within the last 2 years and have been replaced frequently. The charger is original equipment. • 24 V battery and chargers are ~ 10 years old.	• Minimum life expectancy - Batteries - 15-20 years Charger - not assessed.	• Replace 125 V charger in longer term.	• Replace 125 V charger in 2009 - $9k.	• Nil	• Nil
2.1.2.2	**Protection and Control**						
2.1.3	**Cable and Support Systems**						
2.1.4	**Grounding Systems** 230 kV - Solidly grounded 60 kV - Solidly grounded 13.8 kV - Generator voltage system - grounded through distribution transformer 12 kV - Solidly grounded 0.48 kV - AC station service system -ungrounded 0.24/0.12 kV - AC station service system- solidly grounded. 125 VDC - ungrounded		• No significant signs of deterioration of the visible portions of the grounding systems.				
2.1.5	**Lighting Systems** Fluorescent and incandescent lamps with various materials for lighting installation.	• All lighting was rebuilt recently (replacement of incandescent lamps with fluorescent lamps).	• Minimum life expectancy - 15-20 years.	• Replace burnt out lights. • Replace system in longer term.	• Replace lighting system in 2015 - $45k.	• Nil	• Nil

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
2.1.6	**Compressed Air Systems**						
2.1.6.1	**Station Service Air** Compressor supplies air to the generators, air hose and shop service points.		• Fair condition. • Very old reciprocating compressor still functions adequately. • Minimum life expectancy - 15 years.	• Replace with rotary screw compressor in longer term.	• Replace compressor in 2013 - $25k.		
2.1.6.2	**Governor Air** 4 compressors provide air to the governors. A standby compressor provides air direct to the distribution piping.		• Fair condition • Minimum life expectancy - 20 years.				
2.1.7	**Water Systems**					• Nil	• Nil
2.1.7.1	**Raw Water** 5 cooling water system pumps supply cooling water to a main header. The header has branch connections to each generator and transformer cooling system. The header also supplies the air conditioning units and generator lube sets, with a connection to the transformer deluge system.	• Cooling water piping springs leaks continuously. A replacement program is in progress.	• System is in poor condition. Cooling water pumps are badly worn and replacement parts are not available. • Minimum life expectancy - 5-7 years.	• Replace complete cooling water system including pumps. Piping could be upgraded to stainless steel.	• Replace complete cooling water system including pumps in 2001 - $550k.	• Redesign cooling water control for improved water usage on generator stator coolers.	• Design and implement proportional control on cooling water system in 2003 - $650k.
2.1.7.2	**Domestic Water**						
2.1.8	**Drainage Systems**						

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
2.1.9	**Fire Protection System** Cooling water system pumps supply system. Fire protection systems are provided at the generators and transformers. Hose connections are supplied throughout the powerhouse.		• Governor/bearing oil systems do not have fire protection. • Main transformer deluge systems not tested due to nozzle blockage problems.	• Review transformer deluge problem and repair. • Provide governor/bearing oil fire protection and detection.	• Revise fire system to current standards in 1998 - $475k	• Nil	• Nil
2.1.10	**HVAC Systems** Air conditioning is provided by water cooled air conditioning units placed within the Control Room and Equipment Rooms. Heating is provided by electric baseboard heaters located in the Control Room, Offices, Mess Room and Vestibule. Air is exhausted from the powerhouse by means of roof exhausters.		• Systems are in good condition. • No forced ventilation at gallery levels. • Can be upgraded to current practice.	• Revise to current standards.	• Revise HVAC to current standards in 1999 - $100k.	• Nil	• Nil
2.1.11	**Powerhouse Elevator** Elevator type: passenger Capacity: 3000 lbs	• Installed in 1949. • Inspected and certified every 2 years by elevator inspector. • Door mechanism and controls replaced 1995.	• Excellent condition, minimum life expectancy - indefinite.	• Routine maintenance only.	• Nil.	• Upgrade control system.	• Upgrade control system in 2003 - $100k.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
2.2	**Cranes**						
2.2.1	**Powerhouse Crane** Overhead electric bridge crane Main hoist capacity - 175 tons Aux. Hoist capacity - 25 tons Bridge span - 46 ft	• Installed in 1949.	• Main hoist controls overheat if operated at low speed with heavy loads. • Runway and bridge conductors are exposed bare conductors. • Life expectancy - Indefinite	• Regular maintenance. • Rebuild drum controller to allow low speed operation at heavy loads. • Upgrade power conductors to insulated type.	• Upgrade hoist speed control to allow low speed operation at heavy loads by replacing drum controllers with magnetic contactors and upgrade power conductors to insulated type in 1999 - $290k.	• Upgrade to variable frequency drives.	• Upgrade to variable frequency drives in 2004 - $325k.
2.3	**Draft Tube Gates**						
2.4	**Civil Works**						
2.4.1	**Powerhouse Structure** Consists of mass reinforced concrete from the foundation to the generator floor level. From the generator floor to the roof, the superstructure consists of structural steel frames partially encased in reinforced concrete.	• The powerhouse foundation uplift pressures are controlled by relieving high artesian aquifer pressures with ìbleeder wellsî.	• Installation of ìbleeder wellsî has stabilized the powerhouse. • During the rainy season, water leaks into the cable adit through construction and contraction joints. • Conduct seismic evaluation Phase II.	• Maintain ìbleeder wellsî. • Add drains to prevent water leakage into the cable adit. • Carry out any recommendations of the seismic evaluation.	• Add drains to prevent water leakage into the cable adit in 1998 - $20.5k. • Seismic evaluation Phase II and Phase I early attention items in 1999 - $200k.	• Nil	• Nil
2.4.2	**Draft Tube**						
2.4.3	**Tailrace**						

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
2.4.4	**Powerhouse Roof** the powerhouse roof consists of reinforced concrete supported on purlins which are in turn supported on trusses spanning the upstream-downstream direction.	• Nil	• Nil	• Nil	• Nil	• Nil	• Nil
2.4.5	**Oil Containment System** Main transformers and oil storage tanks do not have oil spill containment provisions.		• No oil spill containment exists.	• Upgrade to required standards.	• Upgrade oil containment system in 2003 - $700k.	• Nil.	• Nil.
2.4.6	**Powerhouse Access**						
2.4.7	**Miscellaneous** Drainage systems on hillside above powerhouse. There are 3 drainage systems on the hillside above the powerhouse. They consist of corrugated steel pipes buried or mounted on the surface, surface creeks and an abandoned penstock. They are all interconnected by various concrete catchbasins.	• Drainage system 3 has been experiencing problems during heavy rains and spring run-off. Two large landslides near the penstocks have been attributed to water and mud flows exceeding the capacity of catchbasins of drainage system 3 during flash run-offs. The stability of the penstock hillside above the powerhouse is dependent upon the proper operation of drainage system 3.	• Life expectancy for systems 1 and 2 is ~5-10 years if proper maintenance is continued. • System 3 cannot presently handle flow from its drainage tributary area and should be upgraded.	• Upgrade system 3. • Maintain systems 1 and 2.	• Upgrade system 3 in 1998 - $295k.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
3.0	**Switchyard**						
3.1	**Switchgear**						
3.1.1	**Circuit Breakers** **12CB1**: bulk oil type, 600 A, 500 MVA for main supply of 12 kV feeder to Big Bear Dam and the intakes. **13CB9**: bulk oil type, 15 kV, 3 phase, 3000 A continuous with disconnects combined into unit. Aux. Supply for 12 kV feeder to Big Bear Dam, intakes and townsite. **60CB1-3**: bulk oil type, 3 phase, 69 kV, 800 A continuous, operated at 60 kV.	• 12CB1 – preventative maintenance overhauls conducted in 1991 and 1993. Repairs carried out in 1995. Oil reported in good condition but the contacts are pitted and burnt due to neglect. • 13CB9 – no records of disturbances/faults cleared by this breaker. • 60CB1-3 – 1 and 2 had Doble tests performed in 1995 and 1994 respectively (no results available). CB3 was replaced by the spare 60 kV CB which had a general overhaul before it replaced 60CB3.	• 12CB1 – good condition, minimum life expectancy 10 years. • 13CB9 – good condition, minimum life expectancy 8-10 years. • 60CB1 and 2 – good condition, minimum life expectancy 5-10 years. • 60CB3 – excellent condition, minimum life expectancy 20-25 years.	• 12CB1 – routine maintenance only. • 13CB9 – major overhaul in long term. • 60CB1 and 2 – overhaul both CBs in short term. • 60CB3 – routine maintenance only.	• 12CB1 – Nil. • 13CB9 – major overhaul in 2007 - $30k. • 60CB1 and 2 – overhaul in 1999 - $50k. • 60CB3 – Nil.	• 12CB1 – Nil. • 13CB9 – Nil. • 60CB1-3 – Nil.	• 12CB1 – Nil. • 13CB9 – Nil. • 60CB1-3 – Nil.
3.1.2	**Disconnect Switches**						
3.1.3	**P and C Switchboard** These panels, located in the Powerhouse Control Room, provide primary and standby protection for 2L19, T3, 60L21, 60L22, 60B1, 12VR1, 12VR2 and associated circuit breaker controls and metering.	• With the exception of protective relays T3, 60B1, 12VR1 and 12VR2, all other relays were replaced within the last 5 years.	• Excellent condition, minimum life expectancy 25-30 years.	• Replace remaining original relays in longer term.	• Replace remaining original relays in 2006 - $19k.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
3.2	**Reactive Equipment**						
3.3	**Buswork**						
3.4	**Lightning Arrestors**						
3.5	**Cables**						
3.6	**Grounding Systems**						
3.7	**Civil Works**						
3.8	**Distribution Feeder**						
3.9	**Station Service**						
3.10	**Transformers** **Tie Transformer T5**: 60 MVA, 3 phase, 230 - 12-60 kV, ties the 60 kV bus (for lines 60L21 and 60L22 to Coho and Northern to Line 2L19 to BRT and feeder 12F51 to Big Bear Dam and the intake houses. **Transformer T14**: 2 MVA, 3 phase, 12.6-12.6 kV, delta-wye type. **Transformer 12VR1**: auto-transformer, 9660 kVA, 3 phase, 12.555 kV primary - 11/11.5 kV secondary, 660 kVA, 2300 V tertiary, regulates G3 13.8 kV output. **Transformer 12VR2**: 3750 kVA, 3 phase, 12.5 kV, regulates T5 12 kV output.	• T3 has an important role connecting Northern and Coho to the system and supplying electrical energy (as a backup source) for local consumers. According to records there were no significant signs of disturbances on the transformer. • T14 installed in 1979.	• T3's last gas analysis shows high values of CO and CO2 - signs of cellulose decomposition of the insulation system. 2-Fur level indicates advanced paper aging. Oil is heavily oxidized. Minimum life expectancy - 5-10 years. • T14 is in very good condition. Minimum life expectancy - 5-10 years. • 12VR1 is in good condition. Minimum life expectancy - 5-10 years. • 12VR2 is in poor condition due to oil quality. Minimum life expectancy - 5-10 years.	• T3 - regenerate oil and routine maintenance. • T14 - routine maintenance. • 12VR1 - routine maintenance. • 12VR2 - regenerate oil and routine maintenance.		• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
4.0	**Dam, Forebay and Reservoir**						
4.1	**Dam**						
4.1.1	**Dam No. 1 - Big Bear Dam**						
4.1.1.1	**Dam Structure** Big Bear Dam is a 160 ft high x 366 ft long zoned earth and rockfill embankment. The dam impounds Francis to form Steelhead Lake storage reservoir. A road on the crest of the dam connects Road No. 74 to Pine Mountain road. The abutments of the dam consist mainly of rock that is locally intensely fractured but only superficially altered.		• Minimum life expectancy 20+ years with continued regular maintenance.	• Routine maintenance only.	• Nil.	• Nil.	• Nil.
4.1.1.2	**Dam Drainage and Instrumentation** **Drainage**: four lines of concrete drains are installed under Big Bear Dam to collect seepage water. All 4 drains terminate into a concrete weir located at the downstream toe of the dam. A timber flume located downstream of the dam is used to obtain an indication of the amount and fluctuation of seepage flow bypassing the concrete weir.	• Big Bear Dam is founded on compressible strata and has a history of sinkhole development. • There are a total of 15 foundation settlement plates, 87 monuments, 4 settlement poles, 8 tiltmeters and 7 cut-off rods.	• An instrumentation system should be in place to monitor the dam to forewarn of undesirable events so actions to correct problems can be implemented before the integrity of the dam is jeopardized. • The existing settlement plates, surface monuments, poles, tiltmeters and cut-off rods are beyond their useful life. •	• Replace or repair any missing or damaged instrumentation. • Seal the rods leading to the settlement plates. • Replace or repair gauges and piezometers.	• Seal settlement plate rods in 1998 - $27.5k. • Replace settlement instrumentation in 1998 - $385k. • Repair/replace piezometers in 1998 - $14.2k.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
	Drains under the spillway consist of half pipes or formed channels laid on the concrete and rock contact. Their function is to prevent the build-up of water pressure behind the walls and invert slab. **Instrumentation**: A number of settlement reference points have been established for the purpose of measuring the settlement of Big Bear Dam due to the consolidation of the underlying natural clay stratum. The settlement plate elevations are marked with rods extending form the surface of the dam to the plates. **Piezometers and Gauges**: Piezometers have been installed in various soil strata under the dam to measure seepage or groundwater pressures. Gauges are connected to piezometers are located in a gauge house located near the downstream toe of the dam.		• Rods marking foundation plates may be submerged and, as a result, pressurized water may be introduced to the clay stratum. • Gauges are beyond their useful life - they have not reacted to backflushing and are assumed not to be working.			•	•

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
4.1.1.3	**Reservoir Slopes** **Upstream Slope**: the upper portion of the upstream slope of the Dam is protected by riprap. A thin plastic membrane protects a portion of the upstream impervious clay blanket. **Downstream Slope**: the downstream slope of the dam consists of rockfill at an effective slope of 2.3H:1V	• Riprap protection on the upstream face of the dam is crucial to prevent deterioration of the dam from wave action. • To alleviate the possibility of uneven settlement of the dam causing shear cracks in the impervious core (stony till) and potential leakage through these cracks, a clay blanket was placed on top of the till. A thin plastic membrane was placed on top of the clay blanket to control possible seepage through any cracking that may occur in the clay.	• Minimum life expectancy - 20+ years with continued regular maintenance for both slopes. • Some raveling adjacent to the right hand side abutment has been noticed.	• Regular maintenance.	• Routine maintenance.	• Nil.	• Nil.
4.1.1.4	**Debris Boom**						
4.1.1.5	**Access Roads**						

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
5.0	**Spillway, Intakes and Outlet Works**						
5.1	**Spillway**						
5.1.1	**Spillway No. 1**						
5.1.1.1	**Spillway Structure** The spillway is constructed in an excavation cut into bedrock on the right abutment and comprises a concrete headworks with 2 vertical lift gates, a free overflow section and a curved discharge chute with flip bucket. Spillway flows have formed a plunge pool downstream of the flip bucket.		• Minor spalling of concrete is evident in the spillway, from freeze-thaw and heat from burning debris, with some minor exposure of rebar. • Minimum life expectancy - 20+ years.	• Repair spalled section of spillway. • Monitor condition of spillway over time.		• Nil.	• Nil.
5.1.1.2	**Spillway Gates, Hoists, Controls and Flashboards** **Gates SPOG1 and SPOG2**: Gate type - sluice gate Width - 25 ft Height - 35 ft **Hoists SPOG1 and SPOG2**: Hoist type - vertical screw through driven capstan Motor hp/speed - 50 hp/1200 rpm	• Gates installed in 1949	• Gates in good condition, minimum life expectancy - indefinite. • Hoists in poor condition due to bent cross drive shaft, travel limit switch failure and screw lift threads being exposed requiring regular cleaning. Minimum life expectancy - indefinite.	• Routine maintenance only.	• Nil.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
5.2	**Intakes**						
5.2.1	**Intake No. 1**						
5.2.1.1	**Intake Structure** Power intakes are located on the south shore of Steelhead Lake. Intake consists of an intake-trashrack structure, tower/hoist house and access bridge.		• Structure well maintained. Minimum life expectancy - 20+ years.	• Seismic evaluation.	• Seismic evaluation in 1999 - $23k.	• Nil.	• Nil.
5.2.1.2	**Intake Trashracks** Overall area of trashracks: 21 ft 3 inch x 72 ft 2 inch Bars: 4 inch x 3/8 inch Spacing: 2 3/8 inch centers		• Good condition. • Minimum life expectancy - indefinite.	• Regular inspection only.	• Nil.	• Nil.	• Nil.
5.2.1.3	**Intake Gates and Gantry Crane**						
5.2.1.3.1	**Intake Gate INOG1**: Gate type: fixed wheel Opening size: 14 ft 3 inch high x 11 ft wide Gate size: 15 ft high x 11 ft 6 inch wide **Intake Bulkhead Gate INMG1**: Gate type: bulkhead Opening size: 14 ft 3 inch high x 11 ft wide Gate size: 15 ft high x 12 ft 6 inch wide	• All gates installed 1959/1960.	• Brass facing in one corner of the intake gate is missing which may cause some increase in leakage. Otherwise in good condition. • Bulkhead gate in good condition. • Minimum life expectancy - indefinite.	• Repaint in 15 years.	• Repaint in 2014 - $40k	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
5.2.1.3.2	**Intake Gate Hoist INOG1**: Type: electrically operated drum hoist Capacity: 40 tons Motor hp/speed: 7.5 hp/900 rpm Hoist speed: 1.2 ft/min **Bulkhead Gate Hoist INMG1**: Type: electrically operated drum hoist Capacity: 20 tons Motor hp/speed: 7.5 hp/900 rpm Hoist speed: 4.2 ft/min	• INOG1 installed 1959. • INMG1 installed 1949.	• Intake hoist – good condition except for cable sheaves reported in poor condition. • Bulkhead hoist – good condition. • Minimum life expectancy – indefinite for both hoists.	• Routine maintenance only.	• Nil.	• Nil.	• Nil.
5.3	**Outlet Works**						
5.3.1	**Outlet Works – Big Bear Dam**						
5.3.1.1	**Mid Level Gates, Hoists, Control**						
5.3.1.2	**Outlet and Maintenance Gates** **Low Level Outlet Gates LLOG1 and LLOG2**: Gate type: fixed wheel Width: 8 ft Height: 14 ft **Low Level Maintenance Gates LLMG1 and LLMG2**: Gate type: fixed wheel Width: 8 ft Height: 14 ft	• All gates installed 1960.	• All gates in good condition. • Minimum life expectancy – indefinite.	• Routine maintenance only.	• Nil.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
6.0	**Conduits**						
6.1	**Penstocks** Consist of 4 surface, steel penstocks. Lengths vary from 1700 to 2000 ft (518 to 609 m). All penstocks have an I.D. of 8'-6" (2.59 m), the elevation difference from the start of the penstocks (at the PIV) to the end of the penstocks (at the TIV) is ~426 ft (130 m).		• Good condition, minimum life expectancy - 20+ years with regular maintenance. • There is a concern regarding the stability of the surface penstock hillside which requires attention.	• Routine maintenance. • Check condition of protective coatings and renew protective coatings when required. • Carry out seismic evaluation. • Study stability of penstock footings. • Remove rocks and debris from beneath penstocks. • Install rock barriers in penstock trench.	• Inspect all penstocks and evaluate condition of interior protective coatings /surface in 1998 - $200k. • Study surface penstock footings in 1998 - $18k. • Study surface penstock hillside in 1998 - $40k. • Remove rocks and debris in 1999 - $1,227k. • Conduct seismic evaluation in 1999 - $37.5k. • Wash and apply protective coatings to No. 1 and No. 2 penstocks in 1999 - $420k. • Wash and apply protective coating on interior of No. 1 penstock in 2000 - $710k. • Wash and apply protective coating on interior of No. 2 penstock in 2002 - $710k..	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
					• Install rock barriers in penstock trench in 2003 - $2,484k. • Wash and apply protective coatings to No. 3 and No. 4 penstocks in 2004 - $420k. • Wash and apply protective coating on interior of No. 3 penstock in 2004 - $710k. • Wash and apply protective coating on interior of No. 4 penstock in 2006 - $710k		
6.2	**Diversion Tunnel and Plug** Power tunnel is approximately 3 miles (4.8 km) long. The tunnel is concrete lined for the first 2.4 miles (3.8 km). From the end of the concrete liner, a steel lined section of tunnel branches into two tunnels. The elevation drop of the tunnel from the lake to the penstock inlet valve is 64 ft (19.4 m).	• Head loss measurements have been carried out and indicate satisfactory performance of the tunnel.	• Minimum life expectancy - 20+ years with continued regular maintenance.	• Inspect and repair tunnel as necessary.	• Nil.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
6.3	**Controls**						
6.3.1	**Penstock Inlet Valves** Type: butterfly valve Operating system: hydraulic with DC operated oil pump.	• Installed in 1949.	• Reported in good condition. • Minimum life expectancy - indefinite.	• Routine maintenance only.	• Nil.	• Nil.	• Nil.
7.0	**Control Room Equipment**						
7.1	**Protection and Control** **Control room Panels F1, R1 (A)** These panels provide powerhouse common alarm, transducer, temperature monitoring and auto-synch functions. The Beckwith synchronizer and synchrocloser relays provide automatic synchronizing and manual synchronism checking for unit synchronizing and unit circuit breakers 13CB1 - 13CB4 controls. The panels also house alarm logic card cage for the powerhouse and switchyard. They also provide alarm displays for T1, T2, station auxiliaries and T1 and T2 temperature monitoring. **Station Service Indication and Control Panel R6 (B)**	• Panels A, B and C built as part of the remote upgrade project in 1990. • Panel D built in 1993. Due to noise and other reasons, the tripping functions are blocked due to intermittent false alarms. • Panel E relays were upgraded in 1990 with the exception of the pilot wire relay (HCB). The HCB relays are original equipment. • Most control cables and cable trays were replaced, where feasible, within the last 5 years. Replacement was associated with other P&C upgrades.	• Panels A, B, C and E excellent condition, minimum life expectancy - 20-25 years. • Panel D and control cables and support systems minimum life expectancy - 25-30 years.	• Routine testing only.	• Nil.	• Nil.	• Nil.

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
	These panels, located in the Powerhouse Control Room, provides Station Service control, indication and automatic transfer functions. **12 kV/60 kV Line Control and Indicating Panel F6 (C)** This panel, located in the Powerhouse Control Room, provides 2L19, 60L21, 60L22 and 12F51 indications and CB controls. **Penstock Rupture Protection Panel 40 (D)** This panel provides penstock rupture alarm and protection based on abnormal differential flow between each inlet valve at the valve house and the corresponding unit. Protection function will trip the unit and close the inlet valve. Single path acoustic flowmeters with strap-on transducers are used for flow sensing to the PC based system. **Transformer T1 and T2 Protection Panels (E)** These panels, located in the Powerhouse relay rooms, provide transformer T1 and T2 primary and standby protection and 3L15 and 3L16 pilot wire protection. **Control Cables and Cable Support Systems** Control cable for P&C functions and support systems including cable trays and cable trench.						

Table C-9
Table 4-4 - Step 4-2: Data Analysis and Inspection Results Table for Equipment and Structures (continued)

Asset No.	Equipment or Structure	Performance Information	Results of Assessment	Possible Life Extension Needs	Activities/Projects to meet Needs (including timing and cost)	Possible Modernization Opportunities	Activities to achieve opportunities (including timing and cost)
7.2	**Alarms Indication and Monitoring**						
7.3	**Communications** **SCADA - RTU and Direct Tripping Panel** Two RTUs are installed in the communication room for supervisory control including AGC and generation shedding.	• The RTUs and generator shedding panels were installed within the last 3 years.	• Excellent condition, minimum life expectancy 25-30 years.	• Routine maintenance only.	• Nil.	• Nil.	• Nil.
8.0	**Miscellaneous Buildings**						
9.0	**Diversions**						
9.1	**No. 1 Diversion**						
9.1.1	**Dam**						
9.1.2	**Spillway**						
9.1.3	**Miscellaneous**						

Risk Assessment Spreadsheet
Reference Tables for Use with Spreadsheet

Table (A) - Hazard Codes

Hazard Code	Description
N(e)	Natural (extreme) Earthquake
N(f)	Natural (extreme) Flood
N(s)	Natural (extreme) Storm
S(f)	Security Fire
S(sv)	Security Sabotage/Vandalism
Comp	Compliance - Loss of Water Use
E&P	See Note 1

Table (B) - Category Codes

Risk Category Code (Column 9)	Description
F	Financial
LS	Life Safety
BC	Business Critical

Table (C) - Risk Management Processes

(column 11)

Contingency Plan	
EPP	Emergency Preparedness Plans
EERP	Environmental Emergency Response Plans
OMS	Operating Maintenance and Surveillance
ECS	Emergency communication system
Procedure Changes	
LOO	Local operating order/operations changes

Table C-10
Table 4-5 – Step 4-4: Risk Identification

Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Heading	Component		Failure Mode		Likelihood	Consequences			Risk		Risk Management		R sk Mitigation					Overall importance of risk issues
Description Project	Asset No.	Equipment, Structure, Other	What hazards could occur?	What could happen?	How likely is it to happen?	Financial	Life Safety	Environmental Social	Risk Category	Risk Rating	Are there processes in place to manage risk/what are they?	Are they effective?	Is risk mitigation necessary?	Will the activity be an investigation? Y/N	Will the activity be a project? Y/N	What is the approximate per unit cost? ($K)	What is the likely timing?	
	1.0 Generating Units																	
	1.1.1.4, 1.2.1.4, 1.3.1.4, 1.4.1.4	Turbine Bearing and Lubrication - G1 to G4	E&P - Main bearing failure (low oil level/ oil cooling system rupture)	Loss of generation/ capacity of 1 unit					F		Y; Inspect/alarm/ monitor	Y	Y	N	Y	$132	2001 1998 2002 2000	
	1.1.1.4, 1.2.1.4, 1.3.1.4, 1.4.1.4	Turbine Bearing and Lubrication - G1 to G4	E&P - Thrust bearing failure due to oil film loss at low rev's operator error	Loss of generation/ capacity of 1 unit					F		Y; Inspect/alarm/ monitor	Y	N					
	1.1.2, 1.2.2, 1.3.2, 1.4.2	Governor - G1 to G4	S(f) - Fire at governor/bearing oil systems causes plant outage	Loss of 2 to 4 units/ structure/ equipment/ loss of life					F; LS		Y; Inspection/tests/ alarms/detectors; Fire manual and standards	Y	N					
	1.1.2, 1.2.2, 1.3.2, 1.4.2	Governor - G1 to G4	E&P - Unit overspeed causes failure due governor system failure	Loss of generation/ capacity of 1 unit					F		Y; Inspect/monitor/ unit setting	Y	N					
	1.1.3.2, 1.2.3.2, 1.3.3.2, 1.4.3.2	Actuator - G1 to G4	E&P - Control valve failure at TIV	Loss of generation/capacity					F		N	-	Y	N	Y	$190	2001 1998 2002 2000	
	1.1.4.1, 1.2.4.1, 1.3.4.1, 1.4.4.1	Stator - G1 to G4	E&P - Stator winding failure due to insulation failure	Insulation failure cause damage to generator . Loss of generation					F		N	-	Y	N	Y	$850 - G1, G3 $150 - G2, G4	2001 2008 2002 2000	
	1.1.4.1, 1.2.4.1, 1.3.4.1, 1.4.4.1	Stator - G1 to G4	S(f) - fire in generator	Loss of 1 unit generation water damage/ capacity					F		Y; Alarms/ testing/ inspection/fire standards	Y	N					
	1.1.5, 1.2.5, 1.3.5, 1.4.5	Excitation System - G1 to G4	E&P - Excitation failure lack of parts causes extensive outage	Loss of generation/capacity of 1unit					F		N	-	N					
	1.1.6, 1.2.6, 1.3.6, 1.4.6	Unit Protection and Control - G1 to G4	E&P - Failure of P&C causes unit outage	Loss of 1 unit generation/ capacity					F		Y; Alarms/ testing/ inspection/fire standards	Y	N					
	1.1.9, 1.2.9	Unit Transformers - G1 to G4	E&P/S(sv) oil spill transformer	Loss of 1 to 4 unit generation/ capacity/environmental damage/ loss of rights					F		Y; Inspection/tests/ alarms/ EERP	Y	Y	N	Y	$700	2003	
	1.1.9, 1.2.9	Unit Transformers - G1 to G4	E&P - T1, T2, T3 or T4 failed due to gas production	Loss of 1 unit generation/ capacity					F		Y; Inspection/ tests	Y	N					
		Generation facilities at Francis/Flow to Coho	Comp/E&P Operating outside license guidelines	Loss of rights /capacity/loss of generation.					F		Y; OMS/ LOO/Training	Y	N					
		Generating units at Francis	E&P - Reduced flow discharge capability at Coho reduction in Francis output (contractual obligations)	Loss of 1 to 4 units generation/capacity					F		N	-	N					
		Generating units at Francis	E&P - No flow discharge capability at Coho (no power at Coho)	Loss in capacity/ loss of generation 4 units/ must spill at Big Bear (environmental damage)					F		Alarms/communication/ EPP/OMS/LOO/EERP	Y	N					

Table C-10
Table 4-5 – Step 4-4: Risk Identification (continued)

Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Heading	Component		Failure Mode		Likelihood	Consequences			Risk		Risk Management		Risk Mitigation					Overall importance of risk issues
Description Project	Asset No.	Equipment, Structure, Other	What hazards could occur?	What could happen?	How likely is it to happen?	Financial	Life Safety	Environmental Social	Risk Category	Risk Rating	Are there processes in place to manage risk/what are they?	Are they effective?	Is risk mitigation necessary?	Will the activity be an investigation? Y/N	Will the activity be a project? Y/N	What is the approximate per unit cost? ($K)	What is the likely timing?	
	2.0 POWERHOUSE																	
	2.1 Powerhouse Auxiliary Equipment and Systems																	
	2.1.1.1	Circuit breakers	E&P - Station service 480 V switchgear failure due to switching error	Loss station service/generation /capacity 4 units/					F		Y; Inspect/test/training	Y						
	2.1.1.2	Transformers	E&P - Transformers failure of T11 or T12 due to aging causes reduction in generation	Loss station service/generation reduction 2 units					F		Y; Alarm/test/inspect	Y	Y	N	Y	$199 - T11, T12	2004	
	2.1.1.2	Transformers	E&P - Transformers T13 failure due to overheat violent failure	Loss in capacity/ loss of generation 4 units/ limited spill at Big Bear					F		Y; Alarm/test/inspect	Y	Y	N	Y	$199	2004	
	2.1.7.1	Raw Water	E&P - Cooling water system failure due to main header failure	Loss station service/generation /capacity 4 units					F		Y; Alarm/test/inspect	Y	Y	N	Y	$550	2001	
	2.4	Civil Works	Elk Mtn Slide - Inundation wave on Powerplant	Loss in capacity/ loss of generation/ loss of life (Maintenance staff; plant office)					LS; F		Y; Slope and geological monitoring	Y						
	2.4.1	Powerhouse Structure	Foundation movement failure of structure “bleeder wells” plug of cable adit water damage	Loss in capacity/ loss of generation/					F		Y; OMS	Y	Y	N	Y	$20.5	1998	
	2.4.1	Powerhouse Structure	N(e) Structural failure	Damage to powerplant struct. resulting in loss of capacity/generation /service. Loss of life (office).					LS; F		N	-	Y	N	Y	$200	1999	
	2.4.1	Powerhouse Structure	N(e) Damage to station	Damage to unit(s) resulting in loss of capacity/generation/service.					F		N	-	Y	N	Y	$200	1999	
	2.4.1	Powerhouse Structure	E&P - Deterioration and rupture due to age , settlement foundation movement	Damage to unit(s) resulting in loss of capacity/generation/service.					F		Y; Alarms/ Inspection	Y	Y	N	Y	$20.5	1998	
	2.4.5	Miscellaneous Buildings	E&P - Oil spill from plant/switchyard	Loss or rights/ Loss in capacity/ loss of generation/ loss of generation at downstream plant					F		Y; Detectors/inspection/ OMS/EERP	Y	Y	N	Y	$700	2003	
	2.4.6	Powerhouse Access	Avalanche/slides prevents access	Loss of access/ loss generation due to lack of access to dam					F		Y; Monitoring	Y						
	4.0 DAM, FOREBAY AND RESERVOIR																	
	4.0	Dam, Forebay and Reservoir	E&P -Loss of hydraulic control (upper valve house) due to failure of power supply transformer (25 kVA) supplying power for headworks and spill gates	Loss of energy/ generation/capacity					F		Y; Inspection/ alarm/OMS	Y						
	4.1 Dam																	
	4.1.1	Dam Structure	N(e) - Liquefaction at upstream toe of dam increase seepage loss of dam	Loss of reservoir resulting in loss of capacity/ generation/ energy/loss of rights/environmental damage/ life/ lose access Francis/					BC; LS		Y; Surveillance/ EPP/EERP	Y	Y	N	Y	$200	1999	
	4.1.1	Dam Structure	E&P - Piping failure erodes dam and foundation	Loss of reservoir resulting in loss of capacity/ generation/life/ energy/ loss of rights/ environmental damage /lose access Francis/					BC; LS		Y; OMS/LOO/EPP/EERP /Sinkholes inspection	Y						
	4.1.1	Dam Structure	E&P- Sinkhole degrades critical zone of dam causes dam to be derated lower reservoir level	Loss of capacity/ generation/ energy/ loss of rights/ environmental damage					F		Y; OMS/LOO/EPP/EERP /Sinkholes inspection	Y						

Table C-10
Table 4-5 – Step 4-4: Risk Identification (continued)

Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Heading	Component		Failure Mode		Likelihood	Consequences			Risk		Risk Management		R sk Mitigation					Overall importance of risk issues
Description Project	Asset No.	Equipment, Structure, Other	What hazards could occur?	What could happen?	How likely is it to happen?	Financial	Life Safety	Environmental Social	Risk Category	Risk Rating	Are there processes in place to manage risk/what are they?	Are they effective?	Is risk mitigation necessary?	Will the activity be an investigation? Y/N	Will the activity be a project? Y/N	What is the approximate per unit cost? ($K)	What is the likely timing?	
	4.1.1	Dam Structure	N(s) and (f)- High rainfall ,wind and wave action causes erosion to existing riprap layer fails dam	Loss of reservoir resulting in loss of capacity/ generation/ energy/loss of rights/environmental damage/					F		Y; Inspection/ OMS/EPP/EERP	Y						
	4.1.1	Dam Structure	E&P - Differential settlement crack causes seepage and failure	Loss of reservoir resulting in loss of capacity/ generation/life/ energy/ loss of rights/ environmental damage /lose access Francis/					BC; LS		Y; Inspection/ OMS/EPP/EERP/LO O	Y						
	4.1.3 Reservoir Slopes and Shoreline																	
			See Intakes Below															
	4.1.4	Debris Boom	E&P Debris boom break -Hi flows Spillway Blocks reduce spill capacity/Damage to dam - incipient overtopping	Loss of outflow control - Damage to fish habitat- Loss of capacity/energy					F		Y; Inspection/OMS/ EPP/EERP	Y						
		Hydraulic control of Steelhead Lake/ energy storage for Francis/Coho	Rock slide Area 1 /Area 2 Blockage of spillway chute -Damage to dam /damage to gate hoist structure	Loss of outflow control resulting in loss of capacity/generation/ energy/loss of rights/ environmental damage					F		Y; Monitor/OMS/ EPP/EERP	Y						
		Energy storage for purpose of generation at Francis and Coho; level control on Steelhead Lake	E&P - Loss of local and remote reservoir level indication due to equipment failure ; misoperation of plant causes uncontrolled spill or drawdown	Environmental damage to habitat					F		Y; Inspection/alarm/ testing/OMS/LOO/EE RP	Y						
		Energy storage for purpose of generation at Francis and Coho; level control on Steelhead Lake	E&P Inadvertent drawdown of reservoir/ environmental damage	Environmental damage /loss of rights /capacity/ loss of generation.					F		Y; Training/OMS/LOO	Y						
	5.0 SPILLWAY, INTAKES AND OUTLET WORKS																	
	5.1 Spillway																	
	5.1.1	Spillway	N(e) - Central pier unstable due to extensive cracking	Structural failure/loss of reservoir resulting in loss of capacity/ generation/ energy/loss of rights. environmental damage					F		Y; Monitor/LOO/OMS/ EPP/EERP	Y	Y	N	Y	$200	1999	
	5.1.1	Spillway	E&P Foundation undermining and slipping	Loss of reservoir resulting in loss of capacity/ generation/ energy/loss of rights. environmental damage					F		Y; Inspection/LOO/ OMS/EPP/EERP	Y						
	5.1.1.2	Spillway Gates, Hoists, Controls and Flashboards	E&P Failure of gate to operate due to loss of power supply during flood period	Overtopping/loss of reservoir resulting in loss of capacity/ generation/ energy/loss of rights/ environmental damage					F		Y; Alarms/ surveillance /testing/LOO /OMS/EPP/EERP	Y						
	5.1.1.2	Spillway Gates, Hoists, Controls and Flashboards	E&P - Spill gate hoist stem jams and damages lift mechanism and hoist deck	Uncontrolled release /loss of reservoir resulting in loss of capacity/ generation/ energy/ environmental					F		Y; Testing/inspection/ LOO/OMS/EERP	Y						
	5.1.1.2	Spillway Gates, Hoists, Controls and Flashboards	S(sv) - Vandalism in hoist house damages equipment. Loss of hydraulic control through spillway uncontrolled discharge	Loss of reservoir resulting in loss of capacity/ generation/ energy/ environmental damage					F		Y; Alarms/surveillance/ EPP/EERP/LOO/OM S	Y						
	5.1.1.2	Spillway Gates, Hoists, Controls and Flashboards	N(e) - Rock wedge falls on bridge and spillway No access to spillway/ gates not operative	Loss of reservoir control resulting in loss of capacity/ generation/ energy/access/ loss of rights. environmental damage					F		Y; Inspection/monitor/ OMS/LOO/EPP/EER P	Y						

Table C-10
Table 4-5 – Step 4-4: Risk Identification (continued)

Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Heading	Component		Failure Mode		Likelihood	Consequences			Risk		Risk Management		Risk Mitigation					Overall importance of risk issues
Description Project	Asset No.	Equipment, Structure, Other	What hazards could occur?	What could happen?	How likely is it to happen?	Financial	Life Safety	Environmental Social	Risk Category	Risk Rating	Are there processes in place to manage risk/what are they?	Are they effective?	Is risk mitigation necessary?	Will the activity be an investigation? Y/N	Will the activity be a project? Y/N	What is the approximate per unit cost? ($K)	What is the likely timing?	
	5.2 Intakes																	
	5.2.1	Intake	E&P - Misoperation of units at low reservoir levels causes surging air pocket in tunnel damage to intake structure and equipment	Loss in generation/capacity of 4 units					F		Y; Inspection/ monitor/OMS/LOO	Y						
	5.2.1	Intake	E&P - Reservoir slope slide which blocks intake	Loss in generation/capacity of 4 units					F		Y; Inspection/ monitor/OMS	Y						
	5.2.1.1	Intake Structure	N(e) - Tower collapse/ access bridge collapse	Loss in generation/capacity of 4 units					F		Y; Inspection/OMS	Y	Y	N	Y	$23	1999	
	5.2.1.1	Intake Structure	E&P - Structural failure of the intake towers	Loss in generation/capacity of 4 units					F		Y; Inspection/OMS	Y						
	5.2.1.3	Intake Gates and Hoists	E&P - Damage to LLO sticks open or fails causes uncontrolled release	Environmental damage /loss of rights /capacity/ loss of generation.					F		Y; Surveillance/ EERP	Y						
	5.2.1.3.2	Intake Gate Hoists	E&P - Gate hoist motor fails on overload , single phasing or disconnect switch failure	Loss in generation/capacity of 4 units					F		Y; Inspection/testing/OMS	Y						
	5.2.1.3.2	Intake Gate Hoists	E&P - Gate sticks/jams on opening or closing . (Roller seizes) Lose control of flow into power tunnel	Loss in generation/capacity of 4 units					F		Y; Inspection/OMS	Y						
	6.0 CONDUITS																	
	6.1 Penstocks																	
	6.1.1	Pipe	E&P Penstock vibration - loss of coupling due to improper operation at low reservoir levels causes surging and waterhammer	Loss of 1 unit capacity/generation					F		Y; OMS/ECS	Y						
	6.1.1	Pipe	E&P - Penstock Rupture - Due to large boulder/ hydraulic transients	Loss of penstock/ loss of one gen unit/capacity					F		Y; Inspection/OMS/ECS	Y						
	6.1.1	Pipe	E&P - Large Penstock Rupture- Damage to all 4 penstock foundations /switchyard via water jet	Loss of penstock/ loss of plant powerhouse generation /capacity/switchyard/access road					F		Y; Inspection/OMS/ECS	Y						
	6.1.1, 6.1.2	Pipe/Supports and Anchors	N(e) penstock failure or penstock saddle support failure	Damage to 1 of 4 Penstocks (Loss of 1 unit). Damage to 1 of 2 penstocks (Loss of 2 units)/ access road					F		Y; OMS/ECS	Y	Y	N	Y	$37.5	1999	
	6.1.2	Supports and Anchors	N(s) - High rainfall causes unstable slope undermines saddles of a penstock	Loss of 1 penstock loss of 1 unit at plant					F		Y; Monitor/OMS/ECS	Y						
	6.2	Diversion Tunnels and Plug	E&P - Power tunnel concrete liner failure due to age and settlement or back pressure.	Loss of capacity/generation for 2 units or 4 units					F		Y: Inspection/OMS	Y						
	6.2 (2.1.1)	Diversion Tunnels and Plug	E&P No tunnel hydraulic control due to loss of power supply to upper valve houses due to loss of 480 V AC Bus “B”	Loss of capacity/generation for 4 units					F		Y; Inspection/alarm/ OMS	Y						
	6.3	Penstock Inlet Valves	E&P - Vacuum air valve sticks open filling valve chamber with water	Loss of 1 unit - water leakage makes slope unstable - Loss of generation/ capacity/ lose access road					F		Y; Inspection/testing /OMS	Y						
	6.3	Penstock Inlet Valves	E&P - Vacuum air valve sticks penstock collapse under vacuum	Loss of 1 unit - generation/ capacity					F		Y; Inspection/testing/ OMS	Y						
	6.6	Canal and Headworks	E&P - Failure of steel lined conduit upstream of PIVs	Loss of penstock/ loss of plant powerhouse generation /capacity/switchyard/access road					F		Y; Inspection/testing /OMS/LOO	Y						

Risk Assessment Spreadsheet
Reference Tables for Use with Spreadsheet

Table (A) - Hazard Codes

Hazard Code	Description
N(e)	Natural (extreme) Earthquake
N(f)	Natural (extreme) Flood
N(s)	Natural (extreme) Storm
S(f)	Security Fire
S(sv)	Security Sabotage/Vandalism
Comp	Compliance - Loss of Water Use
E&P	See Note 1

Table (B) - Category Codes

Risk Category Code (Column 9)	Description
F	Financial
LS	Life Safety
BC	Business Critical

Table (C) - Risk Management Processes

(column 11)

Contingency Plan	
EPP	Emergency Preparedness Plans
EERP	Environmental Emergency Response Plans
OMS	Operating Maintenance and Surveillance
ECS	Emergency communication system
Procedure Changes	
LOO	Local operating order/operations changes

Table C-11
Table 4-6 – Step 4-5: Needs

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.1.1.3	G1 Wicket Gates			Refurbish wicket gates	100	50	2001				100																
1.1.1.3	G1 Wicket Gates			Refurbish servomotors	120	50	2001				120																
1.1.1.4	G1 Turbine Bearings and Lube System			Refurbish oil cooling system/pumps and add level sensing equipment	132	50	2001				132																
1.1.1.4	G1 Turbine Bearings and Lube System			Addition of permanent lift pump units	110	50	2001				110																
1.1.2.1	G1 Hydraulic Systems			Refurbish hydraulic pump system	240	50	2014																	240			
1.1.2.2	G1 Governor Controls			Replace governor, valves, aux. Items	1700	50	2014																	1700			
1.1.3.2	G1 Actuator			Modify control valving	190	50	2001				190																
1.1.4.1	G1 Stators			Rewind stator winding	850	35	2001				850																
1.1.4.2	G1 Rotors			Replace rotor core	800	35	2001				800																
1.1.7	G1 Unit Circuit Breakers - 13CB1			Major Overhaul	70	50	2002					70															
1.1.8.3	G1 Generator Switchgear - CTs and PTs			Replace CTs and PTs	38	35	2010													38							
1.1.8.4	G1 Generator Switchgear - Arresters and Capacitors			Replace arresters	32	50	2006									32											
1.1.8.5	G1 Generator Switchgear - Disconnect Switches			Major overhaul	36	35	2011														36						

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.2.1.3	G2 Wicket Gates			Refurbish wicket gates	100	50	1998	100																			
1.2.1.3	G2 Wicket Gates			Refurbish servomotors	120	50	1998	120																			
1.2.1.4	G2 Turbine Bearings and Lube System			Refurbish oil cooling system/pumps and add level sensing equipment	132	50	1998	132																			
1.2.1.4	G2 Turbine Bearings and Lube System			Addition of permanent lift pump units	110	50	1998	110																			
1.2.2.1	G2 Hydraulic Systems			Refurbish hydraulic pump system	240	50	2013																240				
1.2.2.2	G2 Governor Controls			Replace governor, valves, aux. Items	1700	50	2013																1700				
1.2.3.2	G2 Actuator			Modify control valving	190	50	1998	190																			
1.2.4.1	G2 Stators			Clean and rewedge	150	35	2008											150									
1.2.7	G2 Unit Circuit Breakers - 13CB2			Major Overhaul	70	50	2003						70														
1.3.1.3	G3 Wicket Gates			Refurbish wicket gates	100	50	2002					100															
1.3.1.3	G3 Wicket Gates			Refurbish servomotors	120	50	2002					120															
1.3.1.4	G3 Turbine Bearings and Lube System			Refurbish oil cooling system/pumps and add level sensing equipment	132	50	2002					132															
1.3.1.4	G3 Turbine Bearings and Lube System			Addition of permanent lift pump units	110	50	2002					110															
1.3.2.1	G3 Hydraulic Systems			Refurbish hydraulic pump system	240	50	2015																		240		
1.3.2.2	G3 Governor Controls			Replace governor, valves, aux. Items	1700	50	2015																		1700		
1.3.3.2	G3 Actuator			Modify control valving	190	50	2002					190															

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.3.4.1	G3 Stators			Rewind stator winding	850	35	2002					850															
1.3.4.2	G3 Rotors			Replace rotor core	800	35	2002					800															
1.3.7	G3 Unit Circuit Breakers - 13CB3			Major Overhaul	70	50	2003						70														
1.4.1.3	G4 Wicket Gates			Refurbish wicket gates	100	50	2000			100																	
1.4.1.3	G4 Wicket Gates			Refurbish servomotors	120	50	2000			120																	
1.4.1.4	G4 Turbine Bearings and Lube System			Refurbish oil cooling system/pumps and add level sensing equipment	132	50	2000			132																	
1.4.1.4	G4 Turbine Bearings and Lube System			Addition of permanent lift pump units	110	50	2000			110																	
1.4.2.1	G4 Hydraulic Systems			Refurbish hydraulic pump system	240	50	2000			240																	
1.4.2.2	G4 Governor Controls			Replace governor, valves, aux. Items	1700	50	2006			1700																	
1.4.3.2	G4 Actuator			Modify control valving	190	50	2000			190																	
1.4.4.1	G4 Stators			Clean and rewedge	150	35	2000			150																	
1.4.7	G4 Unit Circuit Breakers - 13CB4			Major Overhaul	70	50	2002					70															
1.1.9	Generator Transformers T1A, T1B, T1C (collectively T1)			T1A - replace	350	35	2005								350												
1.1.9	Generator Transformers T1A, T1B, T1C (collectively T1)			T1B - replace	350	35	2008											350									

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																	
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.1.9	Generator Transformers T1A, T1B, T1C (collectively T1)			T1C - replace	350	35	2007										350										
1.1.9	Generator Transformers T1A, T1B, T1C (collectively T1)			T1 protection and alarms - replace pilot wire relay	17	35	2009												17								
1.2.9	Generator Transformers T2A, T2B, T2C (collectively T2)			T2A - replace	350	35	2009												350								
1.2.9	Generator Transformers T2A, T2B, T2C (collectively T2)			T2B - replace	350	35	2010													350							
1.2.9	Generator Transformers T2A, T2B, T2C (collectively T2)			T2C - replace	350	35	2012															350					
1.2.9	Generator Transformers T2A, T2B, T2C (collectively T2)			T2 protection and alarms - replace pilot wire relay	17	35	2009												17								
1.3.9	Generator Transformers T3A, T3B, T3C (collectively T3)			T3A - replace	350	35	2011								350												
1.3.9	Generator Transformers T3A, T3B, T3C (collectively T3)			T3B - replace	350	35	2013											350									
1.3.9	Generator Transformers T3A, T3B, T3C (collectively T3)			T3C - replace	350	35	2014										350										

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																	
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.3.9	Generator Transformers T3A, T3B, T3C (collectively T3)			T3 protection and alarms - replace pilot wire relay	17	35	2009												17								
1.4.9	Generator Transformers T4A, T4B, T4C (collectively T4)			T4A - replace	350	35	2015												350								
1.4.9	Generator Transformers T4A, T4B, T4C (collectively T4)			T4B - replace	350	35	2014													350							
1.4.9	Generator Transformers T4A, T4B, T4C (collectively T4)			T4C - replace	350	35	2016															350					
1.4.9	Generator Transformers T4A, T4B, T4C (collectively T4)			T4 protection and alarms - replace pilot wire relay	17	35	2009												17								
2.1.1	Station Service AC			Relocate and replace 120/240/280 V lighting distribution gallery panel	60	50	1998	60																			
2.1.1	Station Service AC			Replace distribution panels for units	68	50	2006									68											
2.1.1.2	Transformers and Reactors - Transformers T11, T12, T13			T11, T12, T13 - replace all	597	40	2004							597													
2.1.2	Station Service DC			Replace main distribution panels	31	50	2009												31								
2.1.2.1	Battery and Charger Systems			Replace 125 V charger	9	35	2009												9								

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2.1.5	Lighting Systems			Replace lighting system	45	20	2015																		45		
2.1.6.1	Station Service Air			Replace compressor	25	50	2013																	25				
2.1.7.1	Raw Water			Replace complete cooling water system including pumps	550	50	2001				550																	
2.1.9	Fire Protection System			Revise fire system to current standards	475	50	1998	475																				
2.1.10	HVAC Systems			Revise HVAC to current standards	100	50	1999		100																			
2.2.1	Powerhouse Crane			Upgrade hoist speed control to allow low speed operation at heavy loads and upgrade power conductors to insulated type	290	50	1999		290																			
2.4.1	Powerhouse Structure			Add drains to prevent water leakage into the cable adit	20.5	25	1998	20.5																				
2.4.1	Powerhouse Structure			Seismic evaluation Phase II and Phase I early attention items	200	50	1999		200																			
2.4.5	Oil Containment System			Upgrade oil containment system	700	50	2003						700															
2.4.7	Miscellaneous			Upgrade system 3	295	50	1998	295																				
3.1.1	Circuit Breakers - 13CB9			13CB9 - major overhaul	30	40	2007										30											
3.1.1	Circuit Breakers - 60CB1-3			60CB1 and 2- overhaul	50	40	1999		50																			
3.1.3	P&C Switchboard			Replace remaining original relays	19	35	2006									19												

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
4.1.1.2	Dam Drainage and Instrumentation Drainage			Seal settlement plate rods	27.5	50	1998	27.5																			
4.1.1.2	Dam Drainage and Instrumentation Drainage			Replace settlement instrumentation	385	50	1998	385																			
4.1.1.2	Dam Drainage and Instrumentation Drainage			Repair/replace piezometers	14.2	50	1998	14.2																			
5.2.1.1	Intake Structure			Seismic evaluation	23	0	1999		23																		
5.2.1.3.1	Intake Gate INOG1 Intake Bulkhead Gate INMG1			Repaint	40	50	2014																	40			
6.1	Penstocks			Inspect all penstocks and evaluate condition of interior protective coatings/surface	200	50	1998	200																			
6.1	Penstocks			Study surface penstock footings	18	0	1998	18																			
6.1	Penstocks			Study surface penstock hillside	40	0	1998	40																			
6.1	Penstocks			Remove rocks and debris	1227	50	1999		1227																		
6.1	Penstocks			Conduct seismic evaluation	37.5	0	1999		37.5																		
6.1	Penstocks			Wash and apply protective coating on interior of #1 and #2 penstocks	420	50	1999		420																		
6.1	Penstocks			Wash and apply protective coating on interior of #1 penstock	710	50	2000			710																	
6.1	Penstocks			Wash and apply protective coating on interior of #2 penstock	710	50	2002					710															

Table C-11
Table 4-6 – Step 4-5: Needs (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
6.1	Penstocks			Install rock barriers in penstock trench	2484	50	2003						2484															
6.1	Penstocks			Wash and apply protective coatings to #3 and #4 penstocks	420	50	2004							420														
6.1	Penstocks			Wash and apply protective coating on interior of #3 penstock	710	50	2004							710														
6.1	Penstocks			Wash and apply protective coating on interior of #4 penstock	710	50	2006									710												
Identified Project - Total					30,362.7			2187.2	2347.5	3452	2852	3152	3324	1727	700	829	730	850	808	738	36	700	1965	1980	1985	0	0
Unspecified Projects - Allowance of 20% of Annual Average					6,072.5			437.4	469.5	690.4	570.4	630.4	664.8	345.4	140	165.8	146	170	161.6	147.6	7.2	140	393	396	397	0	0
Total					36,435.2			2624.6	2817	4142.4	3422.4	3782.4	3988.8	2072.4	840	994.8	876	1020	969.6	885.6	43.2	840	2358	2376	2382	0	0

Table C-12
Table 4-6 - Step 4-5: Opportunities

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																		
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.1.1.1	G1 Runner			Reshape stay vanes for improved efficiency	185	50	1999		185																			
1.2.1.1	G2 Runner			Reshape stay vanes for improved efficiency	185	50	1999		185																			
1.3.1.1	G3 Runner			Reshape stay vanes for improved efficiency	185	50	2000			185																		
1.4.1.1	G4 Runner			Reshape stay vanes for improved efficiency	185	50	2000			185																		
1.1.1.2	G1 Runner			Replace existing runner with modernized version.	1075	50	1999		1075																			
1.2.1.2	G2 Runner			Replace existing runner with modernized version.	1075	50	1999		1075																			
1.3.1.2	G3 Runner			Replace existing runner with modernized version.	1075	50	2000			1075																		
1.4.1.2	G4 Runner			Replace existing runner with modernized version.	1075	50	2000			1075																		
1.1.1.3	G1 Wicket Gates			Reshape gates for improved efficiency	90	50	1999		90																			
1.2.1.3	G2 Wicket Gates			Reshape gates for improved efficiency	90	50	1999		90																			
1.3.1.3	G3 Wicket Gates			Reshape gates for improved efficiency	90	50	2000			90																		
1.4.1.3	G4 Wicket Gates			Reshape gates for improved efficiency	90	50	2000			90																		
1.1.2.1	G1 Governor Hydraulic System			Replace pump with modernized version.	300	50	2014																	300			
1.2.2.1	G2 Governor Hydraulic System			Replace pump with modernized version.	300	50	2013																300				

Table C-12
Table 4-6 - Step 4-5: Opportunities (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																	
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.3.2.1	G3 Governor Hydraulic System			Replace pump with modernized version.	300	50	2015																		300		
1.4.2.1	G4 Governor Hydraulic System			Replace pump with modernized version.	300	50	2000			300																	
1.1.2.2	G1 Governor Controls			Upgrade to digital control	185	50	2014																	185			
1.2.2.2	G2 Governor Controls			Upgrade to digital control	185	50	2013																185				
1.3.2.2	G3 Governor Controls			Upgrade to digital control	185	50	2015																		185		
1.4.2.2	G4 Governor Controls			Upgrade to digital control	185	50	2000			185																	
1.1.4.1	G1 Generator			Pre-purchase new generator winding.	400	35	1998	400																			
1.1.6.1	G1 Unit Protection			Replace individual relays with microprocessor controlled relay package.	60	35	2000			60																	
1.2.6.1	G2 Unit Protection			Replace individual relays with microprocessor controlled relay package.	60	35	2000			60																	
1.3.6.1	G3 Unit Protection			Replace individual relays with microprocessor controlled relay package.	60	35	2000			60																	
1.4.6.1	G4 Unit Protection			Replace individual relays with microprocessor controlled relay package.	60	35	2000			60																	

Table C-12
Table 4-6 - Step 4-5: Opportunities (continued)

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																	
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2.1.1	Station Service AC			Add emergency services panel.	80	35	2000			80																	
2.1.7.1	Raw Water System			Design and implement proportional control on cooling water system.	650	35	2001				650																
2.1.11	Powerhouse Elevator			Upgrade control system.	100	35	2002					100															
2.2.1	Powerhouse Crane			Upgrade to variable frequency drives.	325	35	2002					325															
Identified Project - Total					7483			400	2220	3025	650	425											485	485	485		
Unspecified Projects - Allowance of 20% of Annual Average					1496.6			80	444	605	130	85											97	97	97		
Total					8979.6			480	2664	3630	780	510											582	582	582		

Table C-13
Table 4-7 – Step 4-6: Strategies/Opportunities Link Sheet

UTILITY STRATEGIC OBJECTIVES	*PERFORMANCE INDICATORS*	*PLANT STRATEGY*	*MODERNIZATION PROJECTS*
1. Utility strategic objective(s) on Investment Investment will create improvements in the following areas: • Strategic impact • Financial benefit • Environmental and social benefit • Risk management	• Shareholder Value Added • Cost of Service • Level of Service	• Improve performance indicators where feasible	• G1 to G4 Runner modernization • G1 to G4 Stay Vane and Wicket Gate modernization
2. Utilities strategic objective(s) on market share Increase market share by: • Trading • Producing additional low cost power	• Cost of Service • Shareholder Value Added • Level of Service	• Improve plant efficiency	• G1 to G4 Runner modernization • G1 to G4 Stay Vane and Wicket Gate modernization
3. Utilities strategic objectives on risk management • Evaluate utility risk exposure • Optimize the utility portfolio exposure	• Shareholder Value Added	• Reduce risk exposure where feasible	• Nil, see life extension projects
4. Utility strategic objectives on stakeholder interests • Identify all major interests • Evaluate improvement alternatives in light of these interests	• Return on Assets • Shareholder Value Added	• Improve ROA and add shareholder value	• G1 to G4 Runner modernization • G1 to G4 Stay Vane and Wicket Gate modernization
5. Utilities strategic objectives on organization and culture • Utility will foster organizational and public support for its commercial operation	• Organizational Climate • Public Opinion • Opinion Leader Assessment	• Project the organization as an active part of the local community	

Table C-14
Table 4-8 - Step 4-7: Opportunities

Asset No.	Equipment/ Structure	Source of Information	Cost Category	Product Description	Total Cost $k	Service Life	Starting Year	Cost per Activity per Year in PV $																	
								1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.1.1.1	G1 Runner			Reshape stay vanes for improved efficiency	185	50	1999		185																		
1.2.1.1	G2 Runner			Reshape stay vanes for improved efficiency	185	50	1999		185																		
1.3.1.1	G3 Runner			Reshape stay vanes for improved efficiency	185	50	2000			185																	
1.4.1.1	G4 Runner			Reshape stay vanes for improved efficiency	185	50	2000			185																	
1.1.1.2	G1 Runner			Replace existing runner with modernized version.	1075	50	1999		1075																		
1.2.1.2	G2 Runner			Replace existing runner with modernized version.	1075	50	1999		1075																		
1.3.1.2	G3 Runner			Replace existing runner with modernized version.	1075	50	2000			1075																	
1.4.1.2	G4 Runner			Replace existing runner with modernized version.	1075	50	2000			1075																	
1.1.1.3	G1 Wicket Gates			Reshape gates for improved efficiency	90	50	1999		90																		
1.2.1.3	G2 Wicket Gates			Reshape gates for improved efficiency	90	50	1999		90																		
1.3.1.3	G3 Wicket Gates			Reshape gates for improved efficiency	90	50	2000			90																	
1.4.1.3	G4 Wicket Gates			Reshape gates for improved efficiency	90	50	2000			90																	
Identified Project - Total					5400				2700	2700																	
Unspecified Projects - Allowance of 20% of Annual Average					1080				540	540																	
Total					6480				3240	3240																	

Francis Plant Life Extension 20 Year Financial Forecast

Federal Power Act Account Description	1998 ($000)	1999 ($000)	2000 ($000)	2001 ($000)	2002 ($000)	2003 ($000)	2004 ($000)
FACILITY INCOME STATEMENT							
Plant Revenues							
Heavy Load Electricity	20,907	21,279	21,279	21,279	21,279	21,279	21,279
Light Load Electricity	3,985	3,985	3,985	3,985	3,985	3,985	3,985
Other							
Total Plant Revenues	**24,892**	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**
Plant Expenses							
403 Depreciation on Existing Capital	0	0	0	0	0	0	0
404-407 Amortization on Existing Capital	685	666	647	629	611	594	577
427 Finance Charges on Existing Capital	1,170	1,156	1,124	1,092	1,062	1,032	1,003
407.3/A Regulatory Debits and Credits	100	100	100	100	100	100	100
Depreciation on New Capital	28	56	78	141	206	290	330
Finance Charges on New Capital	47	98	135	244	358	503	573
Total Plant Expenses	**2,030**	**2,076**	**2,084**	**2,206**	**2,336**	**2,518**	**2,583**
Hydraulic Power Production Expenses - Specific O&M	728	1,300	832	442	582	140	0
Hydraulic Power Production Expenses - Non-Specific							
535 Operation Supervision and Engineering	120	120	120	120	120	120	120
536 Water for Power	5459	5459	5459	5459	5459	5459	5459
537 Hydraulic Expenses (major only)	155	155	155	155	155	155	155
538 Electric Expenses (major only)	100	100	100	100	100	100	100
539 Misc. Hydraulic Power Generation Expenses (major only)	50	50	50	50	50	50	50
540 Rent	0	0	0	0	0	0	0
540.1 Operation Supplies and Expenses (non-major only)	50	50	50	50	50	50	50
541 Maintenance Supervision and Engineering (major only)	100	100	100	100	100	100	100
542 Maintenance Structures (major only)	100	100	100	100	100	100	100
543 Maintenance on Reservoirs, Dams and Waterways (major only)	250	250	250	250	250	250	250
544 Maintenance of Electric Plant (major only)	300	300	300	300	300	300	300
545 Maintenance of Misc. Hydraulic Plant (major only)	50	50	50	50	50	50	50
545.1 Maintenance of Hydraulic Production Plant (non-major only)	100	100	100	100	100	100	100
Total Facility Hydraulic Power Production Expenses	7,562	8,134	7,666	7,276	7,416	6,974	6,834
FACILITY INCOME BEFORE ALLOCATIONS	**15,300**	**15,053**	**15,513**	**15,782**	**15,511**	**15,771**	**15,846**
CONVERSION TO FACILITY CASH FLOW STATEMENT							
Add Depreciation & Finance Charges	1,930	1,976	1,984	2,106	2,236	2,418	2,483
Less Capital Investments	985	1,048	820	2,310	2,470	3,184	1,727
FACILITY NET CASH FLOWS	**16,246**	**15,982**	**16,677**	**15,577**	**15,277**	**15,005**	**16,602**

	At 5 Years	*At 10 Years*	*At 20 Years*
Net Present Value of Facility	***78,030***	***122,553***	***175,156***
Benefit Cost Ratio	***2.59***	***2.62***	***2.63***

Figure C-1
Life Extension Plan Model Results

Francis Feas 5 % Effic Improv. 20 Year Financial Forecast

Federal Power Act Account Description	1998 ($000)	1999 ($000)	2000 ($000)	2001 ($000)	2002 ($000)	2003 ($000)	2004 ($000)
FACILITY INCOME STATEMENT							
Plant Revenues							
Heavy Load Electricity	21,279	21,279	21,279	21,279	21,279	21,279	21,279
Light Load Electricity	3,985	3,985	3,985	3,985	3,985	3,985	3,985
Other							
Total Plant Revenues	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**
Plant Expenses							
403 Depreciation on Existing Capital	0	0	0	0	0	0	0
404-407 Amortization on Existing Capital	685	666	647	629	611	594	577
427 Finance Charges on Existing Capital	1,170	1,156	1,124	1,092	1,062	1,032	1,003
407.3/.4 Regulatory Debits and Credits	100	100	100	100	100	100	100
Depreciation on New Capital	54	108	181	241	304	385	422
Finance Charges on New Capital	92	188	315	419	527	668	733
Total Plant Expenses	**2,102**	**2,219**	**2,367**	**2,481**	**2,604**	**2,778**	**2,836**
Hydraulic Power Production Expenses - Specific O&M	728	1,300	832	442	582	140	0
Hydraulic Power Production Expenses - Non-Specific							
535 Operation Supervision and Engineering	120	120	120	120	120	120	120
536 Water for Power	5459	5459	5459	5459	5459	5459	5459
537 Hydraulic Expenses (major only)	155	155	155	155	155	155	155
538 Electric Expenses (major only)	100	100	100	100	100	100	100
539 Misc. Hydraulic Power Generation Expenses (major only)	50	50	50	50	50	50	50
540 Rent	0	0	0	0	0	0	0
540.1 Operation Supplies and Expenses (non-major only)	50	50	50	50	50	50	50
541 Maintenance Supervision and Engineering (major only)	100	100	100	100	100	100	100
542 Maintenance Structures (major only)	100	100	100	100	100	100	100
543 Maintenance on Reservoirs, Dams and Waterways (major only)	250	250	250	250	250	250	250
544 Maintenance of Electric Plant (major only)	300	300	300	300	300	300	300
545 Maintenance of Misc. Hydraulic Plant (major only)	50	50	50	50	50	50	50
545.1 Maintenance of Hydraulic Production Plant (non-major only)	100	100	100	100	100	100	100
Total Facility Hydraulic Power Production Expenses	7,562	8,134	7,666	7,276	7,416	6,974	6,834
FACILITY INCOME BEFORE ALLOCATIONS	**15,600**	**14,910**	**15,230**	**15,506**	**15,243**	**15,511**	**15,593**
CONVERSION TO FACILITY CASH FLOW STATEMENT							
Add Depreciation & Finance Charges	2,002	2,119	2,267	2,381	2,504	2,678	2,736
Less Capital Investments	1,925	1,988	2,700	2,310	2,470	3,184	1,727
FACILITY NET CASH FLOWS	**15,677**	**15,042**	**14,797**	**15,577**	**15,277**	**15,005**	**16,602**

	At 5 Years	*At 10 Years*	*At 20 Years*
Net Present Value of Facility	***83,755***	***131,179***	***187,355***
Benefit Cost Ratio	***2.67***	***2.69***	***2.71***

Figure C-2
Modernization Plan 5% Efficiency Increase Results

Francis Modernization 5 % Eff Improv. 20 Year Financial Forecast

Federal Power Act Account Description	1998 ($000)	1999 ($000)	2000 ($000)	2001 ($000)	2002 ($000)	2003 ($000)	2004 ($000)
FACILITY INCOME STATEMENT							
Plant Revenues							
Heavy Load Electricity	21,279	21,279	21,279	21,279	21,279	21,279	21,279
Light Load Electricity	3,985	3,985	3,985	3,985	3,985	3,985	3,985
Other							
Total Plant Revenues	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**	**25,263**
Plant Expenses							
403 Depreciation on Existing Capital	0	0	0	0	0	0	0
404-407 Amortization on Existing Capital	685	666	647	629	611	594	577
427 Finance Charges on Existing Capital	1,190	1,156	1,124	1,092	1,062	1,032	1,003
407.3/A Regulatory Debits and Credits	100	100	100	100	100	100	100
Depreciation on New Capital	132	227	286	347	427	464	460
Finance Charges on New Capital	230	395	497	603	742	805	799
Total Plant Expenses	**2,337**	**2,544**	**2,653**	**2,772**	**2,941**	**2,994**	**2,940**
Hydraulic Power Production Expenses - Specific O&M	1,300	832	442	582	140	0	0
Hydraulic Power Production Expenses - Non-Specific							
535 Operation Supervision and Engineering	120	120	120	120	120	120	120
536 Water for Power	5459	5459	5459	5459	5459	5459	5459
537 Hydraulic Expenses (major only)	155	155	155	155	155	155	155
538 Electric Expenses (major only)	100	100	100	100	100	100	100
539 Misc. Hydraulic Power Generation Expenses (major only)	50	50	50	50	50	50	50
540 Rent	0	0	0	0	0	0	0
540.1 Operation Supplies and Expenses (non-major only)	50	50	50	50	50	50	50
541 Maintenance Supervision and Engineering (major only)	100	100	100	100	100	100	100
542 Maintenance Structures (major only)	100	100	100	100	100	100	100
543 Maintenance on Reservoirs, Dams and Waterways (major only)	250	250	250	250	250	250	250
544 Maintenance of Electric Plant (major only)	300	300	300	300	300	300	300
545 Maintenance of Misc. Hydraulic Plant (major only)	50	50	50	50	50	50	50
545.1 Maintenance of Hydraulic Production Plant (non-major only)	100	100	100	100	100	100	100
Total Facility Hydraulic Power Production Expenses	8,134	7,666	7,276	7,416	6,974	6,834	6,834
FACILITY INCOME BEFORE ALLOCATIONS	**14,793**	**15,053**	**15,334**	**15,076**	**15,348**	**15,435**	**15,489**
CONVERSION TO FACILITY CASH FLOW STATEMENT							
Add Depreciation & Finance Charges	2,237	2,444	2,553	2,672	2,841	2,894	2,840
Less Capital Investments	3,748	3,520	2,310	2,470	3,184	1,727	350
FACILITY NET CASH FLOWS	**13,282**	**13,977**	**15,577**	**15,277**	**15,005**	**16,602**	**17,979**

	At 5 Years	*At 10 Years*	*At 20 Years*
Net Present Value of Facility	***82,848***	***129,887***	***185,657***
Benefit Cost Ratio	***2.62***	***2.65***	***2.67***

Figure C-3
Feasibility - 5% Efficiency Increase Results

D
APPENDIX D: ANNOTATED BIBLIOGRAPHY OF LITERATURE RELATED TO VOLUME 1

Volume 1 Annotated Bibliography of Literature INDEX	
KEY FOCUS	**ARTICLE NUMBER**
Asset Management	13, 39
Automation	5, 37, 49
Civil Aspects	4, 29, 48
Condition Monitoring and Diagnosis	6, 18
Protection Control systems	10, 26, 27, 36
Decision-Making	11, 18, 22, 23, 31, 32, 35, 38, 39, 43, 53, 57, 62, 63, 65
Economic Aspects	5, 8, 9, 10, 12, 13, 20, 21, 22, 24, 34, 50, 51, 53, 57, 58,
Electromechanical systems	8, 18, 25, 27
Environmental aspects	15, 16, 59, 66, 71, 82
Evaluation Criteria	8, 14, 17, 18, 19, 20, 23, 30, 38, 43, 45, 55, 56, 58, 61
Generators	1, 5, 21, 27, 47
Guidelines	14, 29
Industrial Sector plants	9
Industry Source Books	87, 88, 89

Volume 1 Annotated Bibliography of Literature
INDEX

KEY FOCUS	ARTICLE NUMBER
Licensing	59, 65, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86
New Technology	1, 40, 46
Optimization	3, 33, 37, 54, 56
Outage Management	31
Partnering	52, 56
Project Management	19, 31, 42, 47, 52
Project Planning	7, 9, 10, 11, 16, 17, 19, 20, 21, 22, 23, 24, 30, 35, 38, 42, 44, 45, 51, 53, 58, 60, 61, 63
Protection Systems	10
Public Safety	78
Pumped Storage	2, 17
R&D	41
Risk/Reliability Analysis	55, 57, 62, 63, 66
Software	6, 30, 33, 37, 54, 63
Stakeholder Involvement	67, 69, 83, 85, 86
Standards	25, 26, 28
Turbines	2, 3, 5, 17, 32, 34, 36, 40, 49, 50, 54, 60, 64
Uprating	1, 5, 40, 47

Volume 1 Annotated Bibliography of Literature on Life Extension, Modernization and Licensing

V 1.1

TITLE	**Applying new technology in the upgrading or upgrating of generators**
AUTHOR	Blecken, W.D. **COUNTRY** USA
PUBLICATION	*International Journal on Hydropower and Dams*. Vol. 4, No. 6. p. 26-32.
DATE	1997
KEY FOCUS	Generators New technology Uprating
SUMMARY	The availability of new materials and improved design methods which permit substantially increased efficiency and output are convincing factors for planning an uprating of generators even with excellent reliability records. Carrying out such a project during a planned turbine refurbishment makes good economic sense. This technical article focuses on target components for upgrading and uprating, and uses 4 case studies to illustrate the advantages of such a scheme. Recommended reading.
VOLUMES	Volume 1 Volume 3 **IMPORTANCE: 1-5** 5
COMMENTS	Author affiliated with Siemens AG, Germany.

V 1.2

TITLE	**Case study for the upgrade and rehabilitation of a pumped storage installation Muddy Run Powerhouse**
AUTHOR	Kepler, James and Jenkins, Thomas **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 3. ASCE, New York, NY. p. 1591-1599.
DATE	1997
KEY FOCUS	Pumped storage Turbines
SUMMARY	Eight 110-MW reversible pump/turbines are involved in a major upgrade at PECo Energy's Muddy Run Storage Powerhouse, Pennsylvania. The rationale for the project and the design of components are discussed.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with Voith Hydro and PECo Energy.

V 1.3

TITLE	**CFD-driven rehabilitation of hydraulic power plants**
AUTHOR	Sebestyen, Andreas, Sallaberger, Manfred, and Keck Helmut
COUNTRY	Switzerland
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 3 ASCE, New York, NY. p. 1719-1728.
DATE	1997
KEY FOCUS	Computational Fluid Dynamics Optimization Turbines
SUMMARY	The use of CFD methods in fast response computations used in relation to turbine modification. The fast procedure results in an estimation of the profit in terms of overall efficiencies due to optimization of the hydraulic performance of the stay-vane profiles.
VOLUMES	Volume 1 Volume 2
IMPORTANCE: 1-5	5
COMMENTS	Authors affiliated with Sulzer Hydro, Zurich, Switzerland.

V 1.4

TITLE	**Civil engineering guidelines for planning and designing hydroelectric developments**
AUTHOR	ASCE **COUNTRY** USA
PUBLICATION	American Society of Civil Engineers' Hydropower Committee of the Energy Division (1995). *Civil engineering guidelines for planning and designing hydroelectric developments,* ASCE, New York, NY. 5 Volumes.
DATE	1995
KEY FOCUS	Civil components Waterways Dams
SUMMARY	Volume 1: Planning, Design of Dams and related features and Environmental Volume 2: Waterways Volume 3: Powerhouses and related topics Volume 4: Small-scale hydro Volume 5: Pumped storage and tidal Power
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 6
COMMENTS	Volumes are available separately.

V 1.5

TITLE	**Combined uprating and refurbishment of the Ybbs-Persenberg scheme**
AUTHOR	Wedam, G., Lenz, M. Hartner, H. **COUNTRY** Austria
PUBLICATION	*International Water Power and Dam Construction*. Vol. 43, No. 10. p. 29-31.
DATE	October 1991
KEY FOCUS	Automation Economic aspects Generators Turbines Uprating
SUMMARY	The simultaneous uprating and refurbishment of plants makes more economic sense. Such an approach is proposed for the 30 year old Ybbs-Persenberg plant on the Danube. The installation of a new unit at the same time as refurbishment will lead to cost savings in the order of US $50 million.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 2 Volume 3
COMMENTS	Authors affiliated with Danube Hydro Austria.

V1.6

TITLE	**A computer aided system for a first estimate of the condition of a hydro power plant**
AUTHOR	Konigsberger, A., Matthias, H-B., and Kafer, K. **COUNTRY** Austria
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants V. Conference Proceedings*. International Water Power and Dam Construction, Sutton, UK, n.p.
DATE	1995
KEY FOCUS	Condition monitoring Software
SUMMARY	Describes the structure of the knowledge-based system, Revex, and the different indicators which support engineers during stocktaking and evaluating separate components and a whole plant. It allows a fast and cost-effective assessment, which can be used as the basis of more detailed studies.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Illustrated with flow charts and screen pages.

V 1.7

TITLE	**Conceptual planning for rehabilitation of the Boundary hydroelectric project**
AUTHOR	Hayes, S and Kobayashi, Vickie **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. v 3 ASCE, New York, NY, USA. p. 1694-1703.
DATE	1997
KEY FOCUS	Project planning
SUMMARY	After an initial focus on rehabilitating the 1051 MW Boundary Hydroelectric Project, from a maintenance perspective, Seattle City Light expanded its scope to include opportunities to enhance or upgrade equipment, systems and facilities. This paper focuses on the conceptual planning process used, the tools developed to analyze and manipulate data on individual work items, costs, schedule, and labor resources; and the final concept plan as it is being implemented.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5

V 1.8

TITLE	**Cost and economics of hydroplant modernisation**
AUTHOR	Castelli, B. Hartmann, O. and Ravicini,L **COUNTRY** Italy
PUBLICATION	*International Water Power and Dam Construction*. Vol.45, No. 12. p. 47-55.
DATE	1993
KEY FOCUS	Economic aspects Electromechanical Evaluation criteria
SUMMARY	Cost information and economics are essential for owners of older plants considering modernization. This paper presents a new methodology for the economic evaluation of modernization projects concentrating on comparative cost data for major plant components. Extensively supported by charts and tables.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 3
COMMENTS	Highly recommended reading. Author Affiliation: ABB, Asea Brown Boveri Power Generation Ltd., Switzerland.

V 1.9

TITLE	**Cost-justifying project improvements in the industrial sector**
AUTHOR	Rohlf, J. and Waldow, G. **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 3. ASCE, New York, USA. p. 1650-1658.
DATE	1997
KEY FOCUS	Economic aspects Industrial sector plants Project planning
SUMMARY	In the industrial/manufacturing sector, major rehabilitation or upgrade programs at hydroelectric facilities must compete with other capital projects for limited investment dollars. Many considerations and creative strategies exist which can help justify the cost of reasonable hydropower investments. This paper discusses an improvement program which was cost-justified and successfully implemented at the Ford Hydro plant, Minnesota.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5** 4

V 1.10

TITLE	**Criteria for the implementation and life cycle management of a major 330 kV protection system upgrade**
AUTHOR	Kerr, D.J. **COUNTRY** Australia
PUBLICATION	*Fifth International Conference on Developments in Power and System Protection,* IEE, London. p. 180-5.
DATE	1993
KEY FOCUS	Project planning Economic aspects Protection systems
SUMMARY	The author documents the development of portion of a six year A$6.1 million upgrade project to provide duplicated and segregated 300 kV protection schemes on the Snowy Mountains Scheme and includes a comparison between main transformer and transmission line protections as previously installed and now in existence. The major difficulty was to reach an agreeable 'cut-off' point to maintain the scope of work within acceptable practical and financial constraints.
VOLUMES	Volume 1 Volume 5 **IMPORTANCE: 1-5** 3
COMMENTS	Author Affiliated with Snowy Mountains Hydro-Electric Authority, NSW, Australia.

V 1.11

TITLE	**Decision support for hydropower plant upgrading: integrating multi-attribute decision making and knowledge based systems**
AUTHOR	Tangen, G. and Stoa, P. **COUNTRY** Norway
PUBLICATION	*ISAP `96. International Conference on Intelligent Systems Applications to Power Systems Proceedings*. Mohammed, O.A. and Tomsovic, K., (eds), IEEE, New York. p. 145-150.
DATE	1996
KEY FOCUS	Project planning Decision-making
SUMMARY	A study of the existing practices for reconditioning strategies in Norwegian hydropower plants revealed several shortcomings: project disparity, multiple participants from different disciplines involved in decision-making and a lack of strategy. The paper argues the need to improve the procedures for ranking reconditioning projects to optimize the allocation of resources and save money. A concept for decision support based on value focused thinking and multi attribute decision making is developed. The two disciplines have different qualities and they can contribute at different stages of the decision process.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Authors affiliated with Energy System Division, Norwegian Electric Power Research Institute, Trondheim, Norway.

V 1.12

TITLE	**Determining O & M costs over the life of a hydro station**		
AUTHOR	Wong, Charles	**COUNTRY**	Canada
PUBLICATION	*Hydro Review*. Vol. IX, No. 6.		
DATE	December 1996		
KEY FOCUS	Budget planning Economic aspects		
SUMMARY	Ontario Hydro's study of the relationship between operation and maintenance costs and a hydro unit's age, and the use of results to predict future costs and to determine budget requirements was the first of its kind. The author of the study reports on the rationale behind the study, the method developed and its application.		
VOLUMES	Volume 1	**IMPORTANCE: 1-5**	5
COMMENTS	Authors affiliated with Ontario Hydro.		

V1.13

TITLE	**Developing a strategy for meeting competition's challenges**
AUTHOR	Nielsen, Niels and Hawley, Nick **COUNTRY** Canada
PUBLICATION	*Hydro Review*. Vol. 17, No. 2. p. 26-30.
DATE	April 1998
KEY FOCUS	Asset management Economic aspects Plant evaluation
SUMMARY	To optimize the commercial value of its hydro power plants BCHydro has implemented an integrated asset evaluation and improvement strategy plan to ensure that its goal is met. An economic modeling process is used to provide a basis for continuous improvement of its hydro plants. Examples of the application of the process and outcomes are documented.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with BCHydro, Vancouver, Canada.

V1.14

TITLE	**Engineering guidelines for the evaluation of hydropower projects**		
AUTHOR	FERC	**COUNTRY**	USA
PUBLICATION	Federal Energy Regulatory Commission. Office of Hydropower Licensing. (1997). *Engineering Guidelines for the Evaluation of Hydropower Projects.* FERC: Washington, DC. 100p.		
DATE	1997		
KEY FOCUS	Evaluation criteria Guidelines		
SUMMARY	Comprehensive guide to the recommended procedures and criteria for reviewing and evaluating hydropower plants in relation to FERC regulations for relicensing.		
VOLUMES	Volumes 1, 2, 4, and 6	**IMPORTANCE: 1-5**	5
COMMENTS	Essential Reference.		

V 1.15

TITLE	**Environmental assessment requirements and process for hydroelectric rehabilitation in Ontario Hydro**
AUTHOR	Yu, M.S. **COUNTRY** Canada
PUBLICATION	*Canadian Electrical Association: Engineering and Operating Division. Hydraulic Power Section 1994 Conference*. Alberta, Canada. 9pp.
DATE	1994
KEY FOCUS	Environmental aspects
SUMMARY	Ontario Hydro has streamlined its environmental assessment process reducing its approval time and resulting in considerable savings.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Author affiliated with Ontario Hydro.

V1.16

TITLE	**Environmental measures for a major dam refurbishment in an urban environment: a case study**
AUTHOR	Lalumiere, Joanne **COUNTRY** Canada
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants IV Conference Proceedings*. International Water Power and Dam Construction, Surrey, UK. p. 159-166.
DATE	1993
KEY FOCUS	Environmental aspects Project planning
SUMMARY	Urbanization around a hydro plant created two kinds of environmental challenges when the spillway had to be replaced. To address noise, dust and safety nuisances and to integrate aesthetic and enhancement measures, environmental advisers were seconded to the site, with unforeseen benefits which went well beyond their initial purpose. The experience showed that a refurbishment project provides an excellent opportunity to improve not only the plant, but its surroundings and the quality of life for those who live nearby.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 6
COMMENTS	Author affiliated with Hydro-Quebec.

V 1.17

TITLE	**Evaluating and specifying pumped storage upgrades**
AUTHOR	Harty, Fred Jr., Geuther, Jeff; Jenkins, Tom Callahan, Tom **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower.* Vol.3 ASCE, New York, NY. p. 1683-1693.
DATE	1997
KEY FOCUS	Evaluation criteria Project planning Pumped storage Turbines
SUMMARY	Increased station capacities in the order of 20% can be achieved by upgrading pumped storage facilities, but only if the upgrade program and equipment specifications take into account all opportunities and constraints. Using the examples of Jersey Central Power and Light's Yards Creek, New Jersey, Susquehanna Electric Company's Muddy Run, and Union Electric's Taum Sauk, Missouri, plants, the paper explores some of the considerations that must be made in specifying an upgrade and in guiding manufacturers toward the design that will give the maximum return to the project.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5** 5
COMMENTS	Recommended reading.

V 1.18

TITLE	**Evaluation criteria for upgrading hydro powerplant**
AUTHOR	Gummer, B., Barr, D. and Sims, G. **COUNTRY** UK
PUBLICATION	*International Water Power and Dam Construction*. Vol. 45, No. 12. p. 24-31.
DATE	December 1993
KEY FOCUS	Condition diagnosis Evaluation criteria Decision-making
SUMMARY	Criteria for an initial multi-disciplined survey to determine the need for a more detailed analysis is applied to economics, operation and maintenance, controls, dams, gates, the power house generating units and ancillary systems. Reasons for problems and alternatives for upgrading are suggested.
VOLUMES	Volume 1,2,3,5,6 **IMPORTANCE: 1-5** 5
COMMENTS	See also *General guidelines for upgrading hydro electric power schemes* by the same authors, who are affiliated with the University of Southhampton and EPD Consultants, Sidcup, UK.

V1.19

TITLE	**General guidelines for upgrading hydro electric power schemes**
AUTHOR	Gummer, B., Barr, D., and Sims, G. **COUNTRY** UK
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants IV Conference Proceedings*. (1993). International Water Power and Dam Construction, Surrey, UK. p. 45-52.
DATE	1993
KEY FOCUS	Evaluation criteria Project management Project planning
SUMMARY	The rehabilitation of hydro facilities should be a multi-disciplined activity which considers far more than the replacement of plant. The paper reviews and analyses the factors to be considered in an initial evaluation, discusses the best agents to carry out the evaluation, and stresses the importance of specification, management and follow-on procedures.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	See also *Evaluation criteria for upgrading hydro powerplants,* by the same authors, in which the focus is on factors to be considered in relation to particular plant components.

V 1.20

TITLE	**Guidance for major rehabilitation projects for fiscal year 1998**
AUTHOR	USACE **COUNTRY** USA
PUBLICATION	Department of the Army. US Army Corps of Engineers. (1995). *Guidance for major rehabilitation projects for fiscal year 1998*. USACE: Washington, DC. (CECW-OM). 14pp.
DATE	1995
KEY FOCUS	Economic aspects Evaluation criteria Project planning
SUMMARY	A guide for use in preparing USACE rehabilitation evaluation reports but relevant to any proposed rehabilitation. Focuses on evaluation criteria with respect to both economic and engineering considerations.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5

V1.21

TITLE	**Hydroelectric generators: repair or refurbishment?**
AUTHOR	Whiteoak, N. and Jeannez, P. **COUNTRY** Europe
PUBLICATION	*GEC Review*, Vol. 12., No. 1. p. 39-47.
DATE	1997
KEY FOCUS	Economic aspects Generators Project planning
SUMMARY	A planned program of refurbishment will lead to economic and output advantages that an unplanned repair program will not. The reasons machines fail, methods of diagnosing their condition and enhancing performance, and the need to use state-of-the art replacement components are discussed. Examples of refurbishment in a typical project are detailed and suggestions given for less conservative means of exploiting the potential for upgraded equipment.
VOLUMES	Volume 1 Volume 3 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with GEC Alsthom UK and France.

V 1.22

TITLE	**Hydro modernization: optimizing economics at an existing plant**
AUTHOR	Lorenz, B. and Baum, U. **COUNTRY** Germany
PUBLICATION	*Hydro Review Worldwide*. Vol. 5, No. 4. p. 10-14.
DATE	September 1997
KEY FOCUS	Economic aspects Decision-making Project planning
SUMMARY	With changes to the electricity market in Europe necessitating modernization, owners of the 80MW Säckingen Hydropower Plant on the Rhine River targeted every aspect of the plant and its operation. The process emphasized economic value as the final planning parameter, and took an innovative approach to involving all plant personnel in the decision-making process. Employee suggestions, alone, saved the company $1.5 million. Costs, only 60% of budget, will be recovered in 7 years instead of the estimated 10.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Recommended reading. Authors affiliated with the plant's ownership company, Rheinkraftwerk Säckingen AG.

V1.23

TITLE	**Hydro-Quebecs' comprehensive approach to analyzing power plants for upgrading**
AUTHOR	Zaikoff, Danielle **COUNTRY** Canada
PUBLICATION	*Uprating and Refurbishing Hydropower Plants IV. Conference Papers.* International Water Power and Dam Construction: Sutton, UK. p. 31-44.
DATE	1993
KEY FOCUS	Assessment criteria Decision-making Project planning
SUMMARY	Presents Hydro-Quebec's methodology for assessing upgrading projects and evaluating the results, focusing on the activating criteria, parameters and indicators and upgrading criteria used. The method of using different implementation scenarios based on the outcomes of these assessments, to determine the program to be adopted, is discussed.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5

V 1.24

TITLE	**Hydro rehab: committing to the future**
AUTHOR	Foster, Bob **COUNTRY** USA
PUBLICATION	*Hydro Review*. Vol. XVII, No. 1. p. 10-17.
DATE	February 1998
KEY FOCUS	Economic aspects Project planning
SUMMARY	The Lower Colorado River Authority used an economic model to evaluate the various rehabilitation alternatives for each of its six plants and for each generating unit within each plant. 15 year operation and maintenance history, condition-monitoring data and personnel inspections provided the basis for the evaluations, which were conducted twice, at the outset and at the planning and engineering phase, and were analyzed against existing and hypothetical future economic and market scenarios. The result has been to increase its capacity by additional 32.5 MW at less than US $1,000 per kw.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Author affiliated with the LRCA, TX.

V 1.25

TITLE	**IEEE guide for the commissioning of electrical systems in hydroelectric power plants**
AUTHOR	IEEE **COUNTRY** USA
PUBLICATION	Institute of Electrical and Electronic Engineers. (1998). *IEEE guide for the commissioning of electrical systems in hydroelectric power plants*. Report # 1248. IEEE, New York.
DATE	1998
KEY FOCUS	Standards Electrical systems
SUMMARY	Up-to-date revised guide to design and application of power plant electrical systems.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 3 Volume 5
COMMENTS	Essential reference. New Standard Report.

V 1.26

TITLE	**IEEE guide for computer-based control for hydroelectric power plant automation**
AUTHOR	IEEE **COUNTRY** USA
PUBLICATION	Institute of Electrical and Electronic Engineers. (1996). *IEEE guide for computer-based control for hydroelectric power plant automation.* Report # 1249-1996, IEEE, New York.
DATE	1996
KEY FOCUS	Standards Control systems
SUMMARY	Up-to-date guide to the application, design and implementation of computer-based control of hydro plant automation. Actual case studies are included.
VOLUMES	Volume 1 Volume 7 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.27

TITLE	**IEEE guide for the rehabilitation of hydroelectric power plants**
AUTHOR	Power Generation Committee of the IEEE Power Engineering Society
COUNTRY	USA
PUBLICATION	Institute of Electrical and Electronic Engineers. (1996). *IEEE guide for the rehabilitation of hydroelectric power plants.* Standard report # 1147-1991. IEEE New York. 48p.
DATE	1996
KEY FOCUS	Control systems Electrical systems Generators Monitoring Turbines Waterways
SUMMARY	A guide to assist in decision-making and design for the rehabilitation of hydroelectric plants covering the assessment of the economic feasibility, the rehabilitation of generators, waterways and electrical equipment and a bibliography of standards, recommended practices and guides.
VOLUMES	Volume 1 Volumes 2,3,4,5,
IMPORTANCE: 1-5	5
COMMENTS:	Essential reference.

V1.28

TITLE	**IEEE standards catalog**
AUTHOR	IEEE **COUNTRY** USA
PUBLICATION	Institute of Electrical and Electronic Engineers. (1998). *IEEE standards catalog*. IEEE Standards Association, Piscataway, N.J. 77p.
DATE	1998
KEY FOCUS	Standards Electrical systems
SUMMARY	Comprehensive listing of IEEE standards publications, products and services.
VOLUMES	Volumes 1, 3, 5, 7 **IMPORTANCE: 1-5** 5
COMMENTS:	Essential reference.

V 1.29

TITLE	**Implementing the federal guidelines for dam safety**
AUTHOR	FERC **COUNTRY** USA
PUBLICATION	Federal Energy Regulatory Commission. (1997) *Implementing the Federal Guidelines for Dam Safety.* FERC,: Washington, DC.
DATE	1997
KEY FOCUS	Dam safety Guidelines
SUMMARY	Describes FERC's actions and activities from October 1, 1995, to September 30, 1997, to implement the *Federal Energy Guidelines for Dam Safety.*
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.30

TITLE	**IT tackles uprating and refurbishments**
AUTHOR	Doujak, Eduard **COUNTRY** Austria
PUBLICATION	*International Water Power and Dam Construction*. Vol. 49, No. 9. p. 44, 46.
DATE	September 1997
KEY FOCUS	Evaluation criteria Project Planning Software
SUMMARY	A software program, REVEX, evaluates hydropower plants and their suitability for uprating and refurbishments, based on a points system, which gives an insight into the condition of the whole plant and its main components, as well as rating their chances for modernization. A priority list for urgent repair work and a detailed report of the plant its other features.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	Development carried out at the Institute for Waterpower and Pumps at Vienna University of Technology. Includes screen page showing evaluation results for the whole plant.

V 1.31

TITLE	**Lessons learned and the rehabilitation of the historic Norris hydro plant**
AUTHOR	Chapman, Lawrence **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. v 3 ASCE, New York, NY, USA. p. 1704-1709.
DATE	1997
KEY FOCUS	Outages Project management Problem-solving
SUMMARY	To address problems during outages the Tennessee Valley Authority adopted an Outage Management Team approach and developed a computerized database of achievements, problems, solutions and lessons learned during previous outages. By using this daily as the basis for discussion on opportunities for improvement in all areas, the outage of the second Norris unit was 91 days less than the first, with considerable cost savings. The article details the TVA approach.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Author affiliated with the Tennessee Valley Authority.

V1.32

TITLE	**Lessons learned from turbine rehabilitation by Seattle City Light**
AUTHOR	Miller, T.R. **COUNTRY** USA
PUBLICATION	*International Journal on Hydropower and Dams*. Vol. 2, No. 4. p. 27-34.
DATE	July 1995
KEY FOCUS	Decision-making Runners Turbines
SUMMARY	In a program to rehabilitate their 16 oldest hydraulic turbines SCL determined that replacing runners with new ones, rather than refurbishing, would lead to an increase of total unit capacity equivalent to a small hydro plant. The article details the work on each of units.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5** 5
COMMENTS	Highly recommended reading. Well illustrated with efficiency charts and design diagrams.

V 1.33

TITLE	**Making money by improving plant efficiency**
AUTHOR	Robitaille, A., Robert, S. and Welt, F. **COUNTRY** Canada
PUBLICATION	*Hydro Review*. Vol. 15, No. 5. p. 92-97.
DATE	August 1996
KEY FOCUS	Data management Optimization Software
SUMMARY	Greater efficiency and significant savings have resulted from the development of Hydro-Quebec's advanced computer-based water management program, GESTEAU, to better understand the causes of efficiency related water spillage and energy losses. Its new version integrates forecasted data which can be processed through a series of hydraulic, optimization and analysis models. Hydro-Quebec expects that optimal levels resulting from the installation of the software in its plants across Quebec will postpone the need for construction of additional hydro plants and provide more energy for export. Charts to illustrate efficiency gains included.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Essential reference.

V1.34

TITLE	**Modernization and performance improvements of vertical Pelton turbines**
AUTHOR	Gass, Matthew **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower.* v 3, ASCE, New York, NY. p. 2073-2082.
DATE	1997
KEY FOCUS	Economic aspects Turbines
SUMMARY	Hetch Hetchy Water and Power, eastern California, is carrying out a major and economical program to modernize, upgrade and increase the performance of 7 of its high head six-jet Pelton turbines. A checklist of items for investigation is given and 3 case studies detail the modifications made to 3 plants, giving costs and efficiency gains.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 2
COMMENTS	Author affiliated with Hetch Hetchy Water and Power, CA. Recommended reading.

V 1.35

TITLE	**Modernization of a complete power plant group**
AUTHOR	Hoepner, S., Ferme, V. and Simeth, G. **COUNTRY** Germany
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants V. Conference Proceedings*. International Water Power and Dam Construction, Surrey, UK. n.p.
DATE	1995
KEY FOCUS	Decision-making Project planning
SUMMARY	The modernization of the Jansen plant was enormous in scope, but very tight on time and budget allocation. This report stresses the need for organization and planning in such situations and focuses on the methods and procedures used. An overview of the decisions made for each of the components is presented.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5** 3

V 1.36

TITLE	**Nantahala control upgrades provide cost savings**
AUTHOR	Neumeuller, Scott, Wright, Jerry **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 1. ASCE, New York. p. 704-712.
DATE	1997
KEY FOCUS	Upgrading Turbines Control systems
SUMMARY	The upgrade of two generating units at the Queen's Creek and Nantahala powerhouses in North Carolina led to reduced costs.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3 Volume 2 Volume 3

V1.37

TITLE	**Optimizing unit allocation: the Norwegian experience**
AUTHOR	Browne, M. and Vinneg, L. **COUNTRY** Norway
PUBLICATION	*Hydro Review Worldwide.* Vol. 3, No. 2. p. 24-27.
DATE	Autumn 1995
KEY FOCUS	Automation Optimization Simulation models Software
SUMMARY	Traditional methods of optimizing load allocation are less than effective in the new power markets. State-of-the art optimization software allows for the development of simulation models which offer an accurate analysis of operating constraints and realistic measurement of potential energy gains and benefits. Norway, where 99.5% of electricity is hydro-produced, has been using such technology for many years, with substantial economic benefits. Supplementary functions include machine condition monitoring and the ability to analyze rehabilitation and uprating options.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Authors affiliated with Norconsult international Norway and Hydropower Technologies Inc., US.

V 1.38

TITLE	**Options for hydro plant rehabilitation**
AUTHOR	Carter, E.F., Clemen, D.M. and Woodbury, M.S. **COUNTRY** USA
PUBLICATION	*International Water Power and Dam Construction.* Vol. 43, No. 10. p. 23-6.
DATE	October 1991
KEY FOCUS	Decision-making Evaluation criteria Project planning
SUMMARY	Focuses on the importance of evaluation and planning procedures in relation to upgrading, modernization, life extension and/or expansion of hydro plants. Account should be taken of the history of the plant, the existing conditions and the limitations of the components and systems before decisions are made.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS:	Authors affiliated with Harza Engineering Co., Chicago, Ilinois.

V 1.39

TITLE	**Overview of EPRI's Generation Asset Management Framework**
AUTHOR	Blanco, M, Broske, D, O'Connor, D, Fahd, G. and Jabbour, S. **COUNTRY** USA
PUBLICATION	Electric Power Research Institute. (1997). *Overview of EPRI's Generation Asset Management Framework.* EPRI, Palo Alto, CA.
DATE	1997
KEY FOCUS	Asset Management Decision-making
SUMMARY	Managing assets for profitability will be the key to success for power generation companies in the competitive marketplace. Traditionally electric utilities have relied on linear, top-down planning processes which cannot easily adapt to a changing business environment. Generation Asset Management (GAM) requires integration of strategy and alignment of decision-making at different levels within the organization, across multiple work processes and functions and over different time frames. This paper gives a synopsis of the industry's issues and needs, an overview of EPRI's proposed GAM model and the organization's R&D program in relation to it.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with EPRI, and Business Management Consulting, Cupertino, CA.

V 1.40

TITLE	**Pelton technology for new plants and modernization schemes**
AUTHOR:	Keck, H; Scharer, Ch., Cuenod, R. and Cateni, A. COUNTRY Europe
PUBLICATION	*International Journal on Hydropower and Dams.* Vol. 4, No. 2. p. 104-108.
DATE	1997
KEY FOCUS	New technology Turbines Uprating
SUMMARY	Recent developments in the field of Pelton turbine technology both for new projects and uprating and refurbishment schemes are discussed. Case studies are included to give some examples of trends in this field.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5**
COMMENTS	Includes case studies.

V 1.41

TITLE	**The possibilities and conditions for refurbishing, uprating and enlarging of hydro power plants in Norway - results from a 6 years investigation programme completed in 1993**
AUTHOR	Jensen, Torodd and Stensby, Hallvard **COUNTRY** Norway
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants IV Conference Proceedings*. International Water Power and Dam Construction, Surrey, UK. n.p.
DATE	1993
KEY FOCUS	Research and development
SUMMARY	Describes main findings from a program to improve the Norwegian Government's knowledge which led to the government's official support of 43 U/R schemes undertaken with an increase of 400GWH/year additional power. A research and development program is ongoing and the authors predict an increase in production by another 4-5 TWh/year because of improved technology of products and methods of construction and operation. One of the program sub projects dealt with compensation water issues.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with The Research Council of Norway and the Norwegian Water Resources and Energy Administration.

V 1.42

TITLE	**Preserving the past, securing the future at Beauharnois**
AUTHOR	Leroux, Gabriel **COUNTRY** Canada
PUBLICATION	*Hydro Review*. Vol. XVI, No. 7. p. SR1-19.
DATE	December 1997
KEY FOCUS	Project planning Project management
SUMMARY	Special report on the Cdn $1.5 billion rehabilitation of this 1,666-MW plant for which Hydro Quebec has adopted an innovative approach to planning and management. Every element of the rehabilitation is planned and scheduled to fit the goal of maximizing power production in the present. In 1995 and 1996 the plant set output records even with the rehabilitation program underway.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	See also *Taking a close look at each rehabilitation opportunity*, which describes the process for the approach taken for designing the components of the program.

V 1.43

TITLE	**Priority criteria in the refurbishing of hydroelectric plants**
AUTHOR	Moretti, A. and Probizer, A. **COUNTRY** Italy
PUBLICATION	*International Water Power and Dam Construction*. Vol. 45, No. 12. p. 44-47.
DATE	December 1993
KEY FOCUS	Decision making Evaluation Prioritization
SUMMARY	The economic-financial aspect of technical solutions related to the refurbishing of aging power plants is complex, and even more so in the case of multiple plants for consideration. ENEL, Venice, which manages 600 plants throughout Italy has developed a quick procedure for analyzing the priority of plants which may be considered as a preliminary stage of the technical-economic feasibility study.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	A technical paper, illustrated with tables. Authors affiliated with ENET DPT, Venice.

V 1.44

TITLE	**Puget Power's hydro modernization project, a diversified approach**
AUTHOR	Haynes, M, Webber, D., Yale, J. **COUNTRY** USA
PUBLICATION	*Waterpower '93. Proceedings of the International Conference on Hydropower.* Vol. 3. ASCE, New York. p. 1671-1680.
DATE	1993
KEY FOCUS	Project planning
SUMMARY	The conceptual design process, specification development and proposed project modifications for the modernization of the 6 power plants in Puget Power's system.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4 Volume 2
COMMENTS	See also *Puget Sound and Light uses EPRI guide in hydro plant modernization effort* for the EPRI report on PSL's use of its modernization guide for stage one of the upgrade program.

V 1.45

TITLE	**Puget Sound and Light uses EPRI guide in hydro plant modernization effort**
AUTHOR	**COUNTRY**
PUBLICATION	Electric Power Research Institute. (1991). *Puget Sound and Light uses EPRI guide in hydro plant modernization effort.* EPRI IN-100801. EPRI, Palo Alto, CA.
DATE	1991
KEY FOCUS	Evaluation Project planning
SUMMARY	To assess potential plant rehabilitation, Puget Sound and Light, WA, sought an approach which would allow in-house engineers to follow a cost-effective generalized procedure for their evaluation program. The use of EPRI's 1989 *Hydropower Plant Modernization Guide*, to specify requirements for computerized modeling of three turbines, prepare a specification for a replacement turbine and to develop a format for use in vendor evaluation and selection resulted in substantial cost savings and increased output.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	See also *Puget Power's hydro modernization project: a diversified approach,* for a report on the subsequent stages of the upgrade program for which the EPRI Guidelines were again used.

V 1.46

TITLE	**Re-energizing an aged hydro plant**		
AUTHOR	Steinmetz, W., Puckett, B., and Torony, J.	**COUNTRY**	USA
PUBLICATION	*Hydro Review*. Vol. 15, No. 2. p. 28 32.		
DATE	April 1996		
KEY FOCUS	New technology State-of-art design		
SUMMARY	The redevelopment of the Berrien Springs Hydroelectric Plant, Michigan, both mechanical and electrical, blends new technology with design innovations, including the use of submersible hydroturbine generators. The article discusses each target of the refurbishment, economic considerations and the alternatives considered as a result.		
VOLUMES	Volume 1	**IMPORTANCE: 1-5**	5
COMMENTS	Authors affiliated with American Electric Power Corporation (AEP), and ITT Flygt Corporation.		

V1.47

TITLE	**Refurbishment and uprating of Tumut 1 and Tumut 2 power stations: a case study**
AUTHOR	Whitby, Roger **COUNTRY** Australia
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants V Conference Proceedings*. International Water Power and Dam Construction, Surrey, UK. n.p.
DATE	1995
KEY FOCUS	Generators Project management Uprating
SUMMARY	The predicted imminent failure of the stator windings prompted this AUD$50 million project. Studies also indicated that the generators could be uprated by 20% for little extra cost and that efficiency and capacity gains could be achieved by upgrading the turbine runners. This 23page report details the technical aspects of the upgrading and how technical and contractual/management problems were overcome.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 2 Volume 3

V 1.48

TITLE	**Refurbishment of the Inkeroinen power plant**
AUTHOR	Lamminpää J. and Robert, D. **COUNTRY** Finland
PUBLICATION	*International Journal on Hydropower and Dams*. Vol. 1, No. 5. p. 26-27.
DATE	September 1994
KEY FOCUS	Civil works Powerhouse
SUMMARY	An innovative engineering solution was used for the refurbishment of the small Inkeroinen plant in Finland. By modifying the hydraulic system it has been possible to retain most of the civil works, and to reduce the number of generating units from four to three, while increasing production by 20%. The solution adopted included the extension of the old powerhouse to accommodate new electrical machinery and reshaping the water passage to suit the design of the new turbines.
VOLUMES	Volume 1 **IMPORTANCE:** 3 **1-5** Volume 6
COMMENTS	Authors affiliated with Enso-Yhteispavelut Oy, and GEC Alsthom Neyrpic Minihydro, France.

V 1.49

TITLE	**Rehabilitation of the High Dam hydroelectric facility**
AUTHOR	Lavigne, John Jr., Cote, William, Nolan, Paul **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower.* Vol. 3. ASCE, New York. p. 2037-2045.
DATE	1997
KEY FOCUS	Automation Turbines
SUMMARY	Modification of existing turbines and conversion to an automated system proved the most cost effective solution to the upgrade of the City of Oswego's power station at the end of the High Dam, Oswego, New York. Capacity has improved from 5.5 MW to 9.2 MW, and a 37% increase in energy is projected.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3 Volume 2 Volume 7
COMMENTS	Includes findings of the preliminary engineering analyses.

V 1.50

TITLE	**Rehabilitation of Unit #2 at Bennett's Bridge Hydro**
AUTHOR	Bernhardt, Paul A. **COUNTRY** USA
PUBLICATION	*Waterpower '93. Proceedings of the International Conference on Hydropower*. Vol. 3. ASCE, New York. p. 1607-1618.
DATE	1993
KEY FOCUS	Economic aspects Turbines
SUMMARY	The project history, economic analysis, index testing method and index test results of the rehabilitation of the #2 horizontal Francis (double discharge) turbine at Bennett's Bridge. A 32% increase in maximum power capacity and an expected life extension of 25 years of that unit led the company to proceed with the rehabilitation of the remaining 3 units.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4 Volume 2
COMMENTS	Good data analysis. Author affiliated with Niagara Mohawk Power Corporation.

V 1.51

TITLE	**Renovating Chippewa Falls Hydro: innovative planning, management**		
AUTHOR	Olson, C	**COUNTRY**	USA
PUBLICATION	*Hydro Review*. Vol. 15, No. 5. p. 39-49.		
DATE	August 1996		
KEY FOCUS	Economic aspects Project planning Rehabilitation		
SUMMARY	Northern States Power Company opted not to use outside contractors for its extensive rehabilitation program. Through careful planning and the use of in-house crews, the project was completed in a year and a half, and the final capital cost was $4 million under initial estimates and $I million under revised budget allowances. Other less tangible benefits in relation to employee morale and work practices were the real gains. The company's planning, implementation and communication procedures are detailed.		
VOLUMES	Volume 1	**IMPORTANCE: 1-5**	5
COMMENTS	Authors affiliated with Northern States Power Company, Wisconsin.		

V 1.52

TITLE	**The renovation of generation facilities : a matter of optimization for electric utilities**
AUTHOR	Astolfi, J-F., Bellin, A., Lavy, P., Rivaz, V. de and Cailmail, X. **COUNTRY** France
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants V Conference Proceedings*. International Water Power and Dam Construction, Surrey, UK. n.p.
DATE	1995
KEY FOCUS	Partnering Project management
SUMMARY	At this time of deregulation operators are often faced with the prospect of rehabilitating aged plants but lack the expertise of major utilities in carrying out such projects. This paper discusses the ROT (Renovation, Operation, Transfer) process developed by Electricité de France, focusing primarily on the meaning of plant renovation and the way this can be carried out in partnership with new owner operators. 2 case histories are included.
VOLUMES	Volume 1 **IMPORTANCE: 1-5**
COMMENTS	Authors affiliated with Electricité de France.

V 1.53

TITLE	**Re-powering Nine Mile Hydroelectric Project**
AUTHOR	Kurrus, J., Zilar, R., Schlect,E., Hokenson, R., Rutherford, J. **COUNTRY** USA
PUBLICATION	*Waterpower 93. Proceedings of the International Conference on Hydropower*. Vol. 3. ASCE, New York. p. 1584-1593.
DATE	1993
KEY FOCUS	Decision-making Economic aspects Project planning
SUMMARY	Washington Water Power evaluated over 200 alternatives for redevelopment, producing cost estimates and energy production for each. The article details all major improvements and the schedule of works which are estimated to result in a 110% increase in generating capacity and extend the plant's life by 50 years.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Emphasis on economic evaluation.

V 1.54

TITLE	**Reviewing the approaches to hydro optimization**
AUTHOR	Sheldon, Lee **COUNTRY** USA
PUBLICATION	*Hydro Review*, Vol. XVII, No. 3. p. 60-67.
DATE	June 1998
KEY FOCUS	Optimization Software Turbines
SUMMARY	A peer reviewed detailed discussion of single unit, powerhouse load and system optimization, and the techniques for achieving them. Methods of testing are discussed and a list of optimization software is provided. An extensive bibliography of material relating to testing and optimization is included.
VOLUMES	Volume 1 Volume 2 **IMPORTANCE: 1-5** 4
COMMENTS	Author affiliated with Kleinschmidt Associates.

V 1.55

TITLE	**Risk-based applications for maintenance and rehabilitation at hydroelectric generating stations**
AUTHOR	Vo, Truong; Norlin, James; Mahan, Brent; Moser, David **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower.* v 3 ASCE, New York, NY. p. 1659-1665.
DATE	1997
KEY FOCUS	Evaluation criteria Reliability analysis Risk analysis
SUMMARY	US Corps of Army Engineers projects with a potential for rehabilitation undergo three analyses : engineering, environmental and economic. In an effort to establish a rehabilitation study methodology which satisfied desired criteria in these areas the Corps sponsored a review of reliability and risk-based applications for major rehabilitation projects. The result was to develop its own risk-based process for the purpose.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	Authors affiliated with USACE. A separate report, CECW-OM 1995, *Guidance for Major Rehabilitation for Fiscal year 1998*, documents the analyses criteria used for assessment by USACE.

V 1.56

TITLE	**Strategic hydropower system rehabilitation**
AUTHOR	Foster, Bob and Schmidt, Stephen **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 2. ASCE, New York. p. 1507-1515.
DATE	1997
KEY FOCUS	Evaluation criteria Optimization Partnering
SUMMARY	Lower Colorado River Authority and Voith Hydro worked jointly to assess alternatives for the optimization of hydro facilities on the Lower Colorado River using a method based on an evaluation of component modification in comparison with hydraulic performance improvement. The partnering led to positive effects in the rehabilitation process, problem-solving and performance outcomes.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Authors affiliated with Lower Colorado River Authority and Voith Hydro.

V 1.57

TITLE	**Summary of studies, research and reports in support of Corps of Engineers rehabilitation and maintenance programs**
AUTHOR	Vo, Truong *et al* **COUNTRY** USA
PUBLICATION	United States Army Corps of Engineers. (1996). *Summary of studies, research and reports in support of Corps of Engineers rehabilitation and maintenance programs.* Technical Report for Contract DE-AC-76RLO-1830. USACE, Portland, Oregon. 51p.
DATE	1996
KEY FOCUS	Decision making Economic evaluation Risk analysis Reliability analysis
SUMMARY	An review of studies, methods and results relating to reliability and risk-based application efforts by USACE and other power industries. The review reveals a wealth of information on reliability and risk analysis, and economic analysis that would be useful for the development of maintenance and rehabilitation programs. Recommendations for further studies are made. An extensive bibliography is included.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Recommended reading. Author affiliated with USACE.

V 1.58

TITLE	**Taking a closer look at each rehabilitation opportunity**
AUTHOR	Rigg, J-P. **COUNTRY** Canada
PUBLICATION	*Hydro Review*. Vol. XVI, No. 7. p. SR12-14.
DATE	December 1997
KEY FOCUS	Economic aspects Evaluation criteria Project planning
SUMMARY	The massive rehabilitation of the Beauharnois Generating Station, Quebec, has been *process*-driven. This article looks at the flexible analytical approach taken in designing the components of the program. Every aspect of the project and its civil and electromechanical components were evaluated prior to the consideration of a range of action options. The ultimate standard was the most economic alternative for making the best use possible of the power potential of the plant.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Author affiliated with Hydro-Quebec. See also *Preserving the past, securing the future at Beauharnois*.

V 1.59

TITLE	**Taking into account the environment in the refurbishing of hydropower plants at Electricité de France**
AUTHOR	Eon, Joseph **COUNTRY** France
PUBLICATION	*Uprating and Refurbishing Hydro Power Plants IV. Conference Proceedings*. International Water Power and Dam Construction, Surrey. p. 123-136.
DATE	1993
KEY FOCUS	Environmental aspects Licensing
SUMMARY	In a situation similar to the US, French hydro plants must comply with operational regulations and legislative regulations based on an environmental impact study for a renewal of their permit. This paper discusses the measures taken by Electricité de France (EDF) to address the implication of these requirements, including a compensation discharge proposal, EDF's models for studying the impact of a change in a regulated flow and initiatives relating to migratory fish.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 3
COMMENTS	Author affiliated with Electricité de France (EDF).

V 1.60

TITLE	**Two approaches to turbine upgrades: planned and unplanned**
AUTHOR	Rittase, R.A. **COUNTRY** USA
PUBLICATION	*International Journal on Hydropower and Dams*. Vol. 2, No. 4. p. 58-64.
DATE	July 1995
KEY FOCUS	Project planning Turbines
SUMMARY	When a major mechanical failure occurs the approach to the rehabilitation of a turbine is very different from a planned upgrade. Apart from deciding on repair action, steps must be taken to ensure that the failure will not be repeated. PECO Energy has had to deal with both types of rehabilitation in recent years at Conowingo and Muddy Run. A comparative study showed the advantages of planning for rehabilitation and outage.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5 Volume 2
COMMENTS	Author affiliated with Voith Hydro Inc., Pennsylvania, USA. Efficiency charts and computer simulations illustrate the paper.

V1.61

TITLE	**Upgrading hydroelectric plants for more efficient operation**
AUTHOR	Bergeret, A. and Mazzoco, M. **COUNTRY** France
PUBLICATION	*Hydro Review Worldwide.* Vol. 1, No. 2. p. 16-21.
DATE	Fall 1993
KEY FOCUS	Evaluation criteria Project planning
SUMMARY	Electricité de France (EDF) operates 250 dams and 550 hydroelectric power stations ranging from 10 KW to 1800 MW and generates some 63 billion KWH of electricity annually. The article shares the lessons learned from a vast refurbishing program.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	EDF is an investor-owned French utility.

V 1.62

TITLE	**Use of hazard analysis in maintenance**
AUTHOR	Wunderlich, Walter COUNTRY USA
PUBLICATION	*Waterpower '93. Proceedings of the International Conference on Hydropower.* Vol. 3. ASCE, New York. p. 1703-1712.
DATE	1993
KEY FOCUS	Hazard analysis Decision-making
SUMMARY	The role of hazard analysis in planning for rehabilitation, using decision analysis to guide investment toward the most effective hazard control alternatives. Quantitative methods for hazard analysis are discussed in detail.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4 Volume 6
COMMENTS	Good use of charts and tables.

V 1.63

TITLE	**The use of Monte Carlo simulation to analyze hydropower rehabilitation proposals**
AUTHOR	Moser, D. et al. **COUNTRY** USA
PUBLICATION	*Waterpower '95. Proceedings of the International Conference on Hydropower*. Vol. 2. ASCE, New York. p. 1087-1096.
DATE	1995
KEY FOCUS	Decision-making Risk analysis Simulation models
SUMMARY	This paper describes the concept of economic risk analysis as prescribed for the US Army Corps of Engineers. The Monte Carlo simulation technique is used in the development of a computer program to analyze rehabilitation proposals and to enable a comparison between total life-cycle costs for the base condition and the immediate rehabilitation alternative.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	Author affiliated with USACE.

V 1.64

TITLE	**What's 'smart' about improving what you have?**
AUTHOR	Nielsen, N. and Keir, G. **COUNTRY** Canada
PUBLICATION	*Hydro Review*. Vol. 13, No. 1. p. 10-19
DATE	February 1994
KEY FOCUS	Efficiency upgrading Project planning
SUMMARY	Under a program called "Resource Smart", BCHydro's hydro plants are being rehabilitated and upgraded. Operating procedures are being overhauled and other measures taken to gain more energy without recourse to a major building project. Since the program began energy gains have been more than 920,000 megawatt-hours-per -year. These additions have cost substantially less than new developments.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with BCHydro, Vancouver, Canada.

Licensing

V 1.65

TITLE	**Alternative relicensing strategies**
AUTHOR	DiGennaro, Bruce **COUNTRY** USA
PUBLICATION	*Waterpower ’97. Proceedings of the International Conference on Hydropower*. Vol. 2. ASCE, New York. p. 868-877.
DATE	1997
KEY FOCUS	Decision-making Licensing process
SUMMARY	Utilities have a number of choices in their approach to the relicensing process. Several specific strategies currently being pursued are presented. The author stresses the need for evaluating the strategy to be adopted in relation to the specific characteristics, goals and objectives of the project.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Author affiliated with EDAW Inc., San Francisco, CA.

V 1.66

TITLE	**Applying for a variance on a minimum flow requirement**
AUTHOR	FERC **COUNTRY**
PUBLICATION	Federal Energy Regulatory Commission. (1992). *Applying for a variance on a minimum flow requirement.* FERC, Washington, DC.
DATE	1992
KEY FOCUS	Licensing Minimum flow requirement
SUMMARY	Discusses the rationale behind, and methods for requesting an amendment to a project license for the purpose of establishing a variance on a minimum flow discharge.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.67

TITLE	**Bending the Rules**
AUTHOR	Moxon, Suzanne **COUNTRY** USA
PUBLICATION	*International Water Power and Dam Construction*. Vol. 50, No. 7 p. 24-29.
DATE	July 1998
KEY FOCUS	Licensing process Stakeholder involvement
SUMMARY	The FERC's licensing and relicensing procedures have caused great debate about the need to reshape them. The Commission's response and its collaborative approach or 'alternative relicensing' process is explained.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS:	2 case studies included.

V1.68

TITLE	**Choosing your best alternative licensing process**
AUTHOR	Fargo, Kelly **COUNTRY** USA
PUBLICATION	*Hydro Review*. Vol. 17. No.3. p. 92-94.
DATE	June 1998
KEY FOCUS	Licensing process
SUMMARY	Uses a Q & A format to briefly explore the nature of the process, the advantages and disadvantages and the economics of it.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 4
COMMENTS	The author was previously employed at FERC where she developed the guidelines for the APEA (Applicant Prepared Environmental Assessments).

V1.69

TITLE	**Cost-effective relicensing: choosing the right process**
AUTHOR	Swiger, Michael and Burns, Steven **COUNTRY** USA
PUBLICATION	*Hydro Review*. Vol. XVII, No. 4. p. 52-61.
DATE	August 1998
KEY FOCUS	Licensing process Stakeholder involvement
SUMMARY	A review of the pro's and con's of the traditional licensing process and the alternative collaborative approach. A guide to assessing projects suited to the collaborative approach is given. The need for licensee applicants to clearly define goals and objectives before settling on the process to be used is stressed.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Highly recommended reding.

V 1.70

TITLE	**Creative conflict resolution: Don Pedro Hydroelectric Project, California**
AUTHOR	Schnagl, J. and Angle, S. **COUNTRY** USA
PUBLICATION	*Waterpower 97. Proceedings of the International Conference on Hydropower*. Vol. 2. ASCE, New York. Pp. 949-956.
DATE	1997
KEY FOCUS	Alternative dispute resolution Licensing
SUMMARY	Describes the case of the Don Pedro application for which FERC initiated an alternative dispute resolution process. Comments on the advantages of this approach.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with FERC but the paper expresses the views of the authors which are not necessarily those of the commission.

V 1.71

TITLE	**EPAct is a timesaver for hydroelectric developers**
AUTHOR	Pen-Jenkins, Monique **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 2. ASCE, New York. p. 887-896.
DATE	1997
KEY FOCUS	Environmental impact statements Licensing
SUMMARY	The Energy Policy Act of 1992 (EPAct) allows for environmental impact statements to be prepared by a third party. Using many specific examples the paper discusses the applicant-prepared and third-party-prepared EA process, the different opportunities and obstacles which may arise from both.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5

V 1.72

TITLE	**Evaluating hydro relicensing alternatives: impacts on power and nonpower values of water resources**
AUTHOR	Boyd, D., Neae, R., Rice, J. and Taleb-Ibrahimi, N. **COUNTRY** USA
PUBLICATION	Boyd, D., Neae, R., Rice, J. and Taleb-Ibrahimi, N. (1990). *Evaluating hydro relicensing alternatives: impacts on power and nonpower values of water resources*. EPRI GS-6922. EPRI, Palo Alto, CA. 64p.
DATE	1990
KEY FOCUS	Licensing methodology
SUMMARY	EPRI has developed a methodology, consistent with FERC requirements, which integrates techniques of cost-benefit and decision analysis to guide utilities in evaluating and ranking hydro relicensing alternatives. It encourages applicants to creatively identify relicensing alternatives that will increase net public benefits. Prior to publication the methodology was trialed in 3 actual cases and the draft report received extensive review from the hydro industry as well as from state and federal resource agencies and recreational/environmental groups.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	See also V1. *FERC supports EPRI HYDRO relicensing methodology.*

V 1.73

TITLE	**Evaluating relicensing proposals at the Federal Energy Regulatory Commission**
AUTHOR	Fargo, J.M. **COUNTRY** USA
PUBLICATION	Fargo, J.M. (1991). *Evaluating relicensing proposals at the Federal Energy Regulatory Commission*. Paper No. DPR-2. FERC, Office of Hydropower Relicensing, Washington, DC.
DATE	1991
KEY FOCUS	Licensing
SUMMARY	Discusses FERC's economic evaluation of relicense proposals and how it uses the results of economic and environmental studies to choose the option that gives the greatest benefit to the public.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference. Free of charge.

V 1.74

TITLE	**Federal regulation of hydro power : what changes are necessary to allow hydro power to compete in the new competitive market?**
AUTHOR	Bock, Eric **COUNTRY** USA
PUBLICATION	*Waterpower ’97. Proceedings of the International Conference on Hydropower*. Vol. 3. ASCE, New York. p. 1868-1877.
DATE	1997
KEY FOCUS	Licensing
SUMMARY	Discusses the evolution of hydropower regulation in the US, summarizing the various acts and FERC Programs, the current licensing process and proposed changes to Federal laws and regulations.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Useful overview of the current situation.

V 1.75

TITLE	**FERC license implementation and lessons learned**
AUTHOR	Gaffney, S. **COUNTRY** USA
PUBLICATION	*Waterpower '97. Proceedings of the International Conference on Hydropower*. Vol. 2. ASCE, New York. p. 971-979.
DATE	1997
KEY FOCUS	Licensing process
SUMMARY	The implementation phase of the relicensing process is subject to a process of its own. A number of problems may arise. The paper outlines the process, the options available to the licensee, and then, in a problem and solution format presents a list of lessons learned from being involved in the process. Highly recommended reading.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Author affiliated with Duke Power Co., Charlotte, NC.

V 1.76

TITLE	**FERC supports EPRI hydro relicensing methodology**
AUTHOR	EPRI **COUNTRY** USA
PUBLICATION	Electric Power Research Institute. (1991). *FERC supports EPRI HYDRO relicensing methodology*. IN-100002. EPRI, Palo Alto, CA.
DATE	1991
KEY FOCUS	Licensing methodology
SUMMARY	EPRI has developed a methodology, consistent with FERC requirements, which integrates techniques of cost-benefit and decision analysis to guide utilities in evaluating and ranking hydro relicensing alternatives. It encourages applicants to creatively identify relicensing alternatives that will increase net public benefits. In one reported case the use of the methodology identified a relicensing alternative which resulted in the increase of the value of the water resource by $13.4 million.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	See also V1. *Evaluating hydro relicensing alternatives: impacts on power and nonpower values of water resources*, EPRI GS-6922, for the methodology itself.

V 1.77

TITLE	**Guide to the hydroelectric license and exemption amendment process**
AUTHOR	FERC **COUNTRY** USA
PUBLICATION	Federal Energy Regulatory Commission. (1992). *Guide to the hydroelectric license and exemption amendment process*. FERC, Washington, DC.
DATE	1992
KEY FOCUS	Licensing
SUMMARY	Step-by-step procedures to amend a license or an exemption from license. It does not cover changes to a license application.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.78

TITLE	**Guidelines for public safety at hydropower projects**
AUTHOR	FERC **COUNTRY** USA
PUBLICATION	Federal Energy Regulatory Commission. (1992) *Guidelines for public safety at hydropower projects*. FERC, Washington, DC.
DATE	1992
KEY FOCUS	Licensing Safety issues
SUMMARY	Background information to assist with assessment of public safety at hydropower projects.
VOLUMES	Volume 1 Volume 6 **IMPORTANCE: 1-5** 5

V 1.79

TITLE	**Hydroelectric project licensing handbook**
AUTHOR	FERC **COUNTRY** USA
PUBLICATION	Federal Energy Regulatory Commission. (1991). *Hydroelectric Project Licensing Handbook*. FERC, Washington, DC.
DATE	1991
KEY FOCUS	Licensing process
SUMMARY	Guide to the licensing process which can be used by all stakeholders and FERC staff in the development, review and processing of applications.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.80

TITLE	**Hydroelectric project relicensing handbook**
AUTHOR	FERC **COUNTRY** USA
PUBLICATION	Federal Energy Regulatory Commission. (1991). *Hydroelectric Project Relicensing Handbook*. FERC, Washington, DC.
DATE	1991
KEY FOCUS	Licensing process
SUMMARY	Step-by-step guide to the relicensing process with the aim of improving the quality and consistency of relicense applications.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference, but “not a substitute for the regulations themselves.”

V 1.81

TITLE	**Hydro operational restrictions forum: licensee workshop summary**
AUTHOR	O'Shea, Thomas **COUNTRY** USA
PUBLICATION	*Hydro operational restrictions forum: licensee workshop summary* (1998). TR-111073. EPRI, Palo Alto, CA. 64pp.
DATE	1998
KEY FOCUS	Economic aspects Licensing process
SUMMARY	The complexity, duration and cost of the hydro relicensing process can be reduced if applicants are not always "reinventing the wheel". There is also a need to avoid imposition of unreasonable, unnecessary or ineffective mitigation measures as conditions for renewal, which in many cases pose severe operational and economic penalties Fifteen licensing representatives with recent or current involvement in the shared experiences of the relicensing process. A second workshop solicited input from agencies and NGO's to the need for, and scope of, a compendium of preferred practices.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5

V 1.82

TITLE	**Hydropower licensing and endangered species- procedures for complying with the Endangered Species' Act**
AUTHOR	FERC **COUNTRY**
PUBLICATION	Federal Energy Regulatory Commission. (1993) *Hydropower licensing and endangered species- procedures for complying with the Endangered Species' Act*. FERC,: Washington, DC.
DATE	1993
KEY FOCUS	Endangered species Environmental aspects Licensing
SUMMARY	Describes procedures Commission staff must follow to evaluate the effects of hydropower development on threatened and endangered species.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.83

TITLE	**Landmark agreement brings new approach to relicensing**
AUTHOR	Hayen, Rita and Geary, Dennis **COUNTRY** USA
PUBLICATION	*Hydro Review*. Vol. XVI, No. 1. p. 18-24
DATE	February 1997
KEY FOCUS	Licensing process Stakeholder involvement
SUMMARY	While other hydropower licensees have used settlement agreements to address unresolved resource issues, Wisconsin Electric Power Company's Wilderness Shores Settlement Agreement resolves all natural resource, recreational and operational issues relating to 8 projects prior to the time of relicensing deadline. The agreement demonstrates the benefits to all stakeholders from the cooperative process.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Authors affiliated with Wisconsin Electric, and Mead and Hunt, Madison, WI.

V 1.84

TITLE	**Reinventing electric utility regulation**
AUTHOR	Enholm, G. and Malko, J. R. (eds) **COUNTRY** USA
PUBLICATION	*Reinventing electric utility regulation* (1995). Public Utilities Reports, Vienna, VA. 502p.
DATE	1995
KEY FOCUS	Licensing
SUMMARY	Comprehensive reference to the present nature and future of US electric utility regulation in three sections. The first presents background information, the core consists of detailed historical, current and future prospects for 11 state regulatory commissions and the final section provides perspectives from various key participants in the regulatory process.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Essential reference.

V 1.85

TITLE	**Water resource management and hydropower: guidebook for collaboration and public involvement**
AUTHOR	EPRI **COUNTRY** USA
PUBLICATION	Electric Power Research Institute. (1991). *Water resources management and hydropower: guidebook for collaboration and public involvement*. EPRI TR-104858. EPRI, Palo Alto, CA. 330p.
DATE	1991
KEY FOCUS	Licensing process Stakeholder involvement
SUMMARY	Aware of the escalating costs of relicensing, and the potential loss of hydro generation as a result of the new FERC guidelines, EPRI aimed to develop a guide to the relicensing process which improved communications between, and involvement of, all stakeholders early in the process, and enabled utilities to communicate the benefits of hydro, and avoid or minimize loss of generation. EPRI conducted 50 interviews and 10 focus group meetings with a full range of hydro stakeholders. The resulting Draft Guidebook was then used in four utility case study applications with Alabama Power Company, Idaho Power Company, Northern States Power Company and Tennessee Valley Authority.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Highly recommended reading.

V 1.86

TITLE	**Working collaboratively to protect the environment while producing electricity**
AUTHOR	La Bolle, Larry, D. and Mack, Sandrah **COUNTRY** USA
PUBLICATION	*Hydro Review*. Vol.17, No. 2. p. 12-16
DATE	April 1998
KEY FOCUS	Licensing process Stakeholder involvement
SUMMARY	From the FERC's perspective a settlement agreement that becomes part of a license application would certainly streamline its approval process. Washington Water Power is using the collaborative approach to relicensing, working with water resource stakeholders to develop agreements on many issues. The paper documents WWP's process and the response of various stakeholders.
VOLUMES	Volume 1 **IMPORTANCE: 1-5** 5
COMMENTS	Recommended reading.

Industry Sourcebooks

V 1.87

TITLE	***Hydro Review* 1998 industry sourcebook: your complete hydro reference**
AUTHOR	**COUNTRY** USA
PUBLICATION	*Hydro Review 1998 industry sourcebook: your complete hydro reference.* Volme XVI, No. 8. HCI, Kansas City, MO. 180p.
DATE	1998
KEY FOCUS	Company listings Manufacturers Product guides
SUMMARY	Annual industry source book with comprehensive listings of companies, services, products, organizations and agencies.
VOLUMES	Volumes 1-7 **IMPORTANCE: 1-5** 5
COMMENTS	Annual reference from the publishers of *Hydro Review* journal.

V 1.88

TITLE	***International Water Power and Dam Construction*: Yearbook 1998**
AUTHOR	**COUNTRY** USA
PUBLICATION	*International Water Power and Dam Construction: Yearbook 1998.* (1998). Wilmington Business Publishing, Dartford, Kent. 250p.
DATE	1998
KEY FOCUS	Company listings Manufacturers Product guides
SUMMARY	Comprehensive annual guide to the international hydro industry featuring organizations, ICOLD committees, recent contract details, statistics related to dams, and an extensive buyers' guide listing company data, and products and services by category.
VOLUMES	Volumes 1-7 **IMPORTANCE: 1-5** 5
COMMENTS	Annual reference from the publishers of *International Water Power and Dam Construction*. Special feature database related to the world's large hydropower caverns is included in this issue.

V 1.89

TITLE	***Hydro Review Worldwide* 1998-1999 Hydro Directory**
AUTHOR	**COUNTRY** USA
PUBLICATION	*Hydro Review Worldwide. Vol. 6. No. 3.* (1998). HCI, Kansas City, Mo. 110p.
DATE	1998
KEY FOCUS	Company listings Manufacturers Product guides
SUMMARY	Annual industry source book with listings of companies, services, products, organizations and agencies.
VOLUMES	Volumes 1-7 **IMPORTANCE: 1-5** 5
COMMENTS	Annual reference from the publishers of *Hydro Review Worldwide.*